Electrophysiologic laryngeal nerve monitoring in high-risk thyroid surgery

Phillip Song, MD; Larry Shemen, MD, FRCS, FACS

Abstract
We recently began performing intraoperative electrophysiologic monitoring of the recurrent laryngeal nerve and the external branch of the superior laryngeal nerve during high-risk thyroidectomies. Neuromonitoring can detect stimulation of these nerves and thereby prevent a mechanical or thermal injury that can result in neurapraxia or axonotmesis. Monitoring is also useful during dissection in an already operated-on field, when performing thyroidectomy on patients who depend on their voice for their livelihood, and when removing a large goiter or mediastinal mass.

Introduction
Recent advances in electrophysiologic monitoring have facilitated the identification of the recurrent laryngeal nerve (RLN) and the external branch of the superior laryngeal nerve (EBSLN) during thyroid surgery. Damage to either of these nerves can result in significant impairment of vocal, swallowing, and respiratory functions. Although RLN monitoring has become increasingly commonplace, monitoring of the superior laryngeal nerve is performed much less often.

We describe 4 cases of high-risk thyroidectomy in which we elected to monitor the RLN and EBSLN. These patients were chosen for monitoring because we anticipated difficulties during nerve dissection or because their specific vocation placed a high priority on vocal performance. Monitoring of the RLN was accomplished by using either a postcricoid surface electrode plate or an endotracheal tube equipped with electrodes attached to an NIM-2 monitor (NIM-Response 2.0 Nerve Integrity Monitoring System; Medtronic Xomed; Jacksonville, Fla.). The EBSLN was monitored in all 4 cases by bipolar electromyographic (EMG) needle electrodes placed in the cricothyroid muscle. The purpose of this article is to present rational guidelines for the use of electrophysiologic laryngeal nerve monitoring during thyroid surgery.

Case reports
Patient 1. We evaluated a 38-year-old woman who had been diagnosed with papillary cancer 7 years earlier. At that time, she underwent a total thyroidectomy and paratracheal lymph node dissection, and she received two courses of radioactive iodine (147 mCi 7 years prior to presentation, and 158 mCi 5 years prior). On routine follow-up, she was found to have an elevated thyroglobulin level (15.2 ng/ml), and she was referred to our department. Results of a thyrotropin study were negative. Ultrasonography and computed tomography detected three pathologically enlarged paratracheal and suprasternal nodes.

The patient underwent an uneventful paratracheal and suprasternal lymph node dissection. RLN monitoring was performed with a postcricoid surface electrode plate placed by the surgeon. Six positive lymph nodes were recovered from the suprasternal and superior mediastinum. The patient’s postoperative thyroglobulin level was 0. Her voice quality was undisturbed.

Patient 2. A 46-year-old woman, an opera singer, presented with a 3-cm mass in the right thyroid lobe. Fine-needle aspiration cytology revealed that the mass was a follicular adenomatous nodule. Thyroid lobectomy and isthmusectomy were performed. RLN monitoring was accomplished by using the EMG-equipped endotracheal tube. Final pathology identified the mass as a multinodular goiter. The quality of the patient’s voice was undisturbed, and she was able to sing in the recovery room.

Patient 3. A 47-year-old woman, also a singer, presented with a large neck mass. Her history was notable for radiation exposure. Fine-needle aspiration cytology revealed that the mass was a follicular adenomatous nodule. Thyroid lobectomy and isthmusectomy were performed. RLN monitoring was accomplished by using the EMG-equipped endotracheal tube. Final pathology identified the mass as a multinodular goiter. The quality of the patient’s voice was undisturbed, and she was able to sing in the recovery room.

Patient 4. A 47-year-old woman, also a singer, presented with a large neck mass. Her history was notable for radiation exposure. She was found to have a massive goiter with mediastinal extension, and she underwent a total thyroidectomy. Intraoperatively, her thyroid was found to measure 12 × 10 × 7 cm. RLN monitoring was achieved with the EMG-equipped endotracheal tube. During delivery of the retrosternal thyroid, the nerve discharged several times; as a result, less aggressive traction was placed on...
the thyroid. After removal of the thyroid, the integrity of the RLN and EBSLN was tested with the electrode stimulator and found to be intact. The procedure was otherwise uneventful. The patient’s voice was undisturbed, and she was able to resume singing 2 weeks later.

**Patient 4.** A 45-year-old man presented with a bilateral, fixed, rock-hard thyroid. Findings on fine-needle aspiration cytology suggested lymphocytic sclerosing thyroiditis. A total thyroidectomy was performed, and RLN monitoring was achieved by using the EMG-equipped endotracheal tube. Intraoperatively, the thyroid was found to be densely fibrotic and adherent to the surrounding structures. The nerve monitor discharged several times during retraction of the thyroid. Postoperative fiberoptic laryngoscopy revealed a weakness of the right RLN. The patient experienced some postoperative hoarseness, but it resolved within 2 weeks.

**Discussion**

The purpose of nerve monitoring is to confirm localization of the nerve and to prevent retraction or electrical injury. We use the nerve stimulator to facilitate nerve localization in areas of heavy fibrosis. After we identify the nerve, we check the nerve integrity with the electrode stimulator. During an operation, the nerve monitor helps prevent inadvertent traction and thermal or dissection injury. Nerve monitoring facilitates careful nerve dissection and localization, and it can be applied to both the RLN and EBSLN. The monitoring does not change the operative technique.

**RLN injury.** Specific sequelae of RLN injuries include poor voice quality, hoarseness, increased aspiration, and respiratory compromise. In a study of 1,026 thyroid surgeries published in 1994, Wagner and Seiler reported that 5.9% of patients experienced RLN injury and that 2.4% of the 1,026 patients experienced permanent vocal fold paralysis.1

The most common method of removing the thyroid involves identification and dissection of the RLN up to the point where it enters the larynx. The risk of injury to the nerve increases with the operation’s level of difficulty. In patients who have a history of revision surgery or scarring from previous neck operations, the RLN can be obscured and therefore jeopardized during dissection.2 Thyroid and parathyroid reoperations in particular pose an increased risk of nerve damage. In reoperations, scar and healing tissue distort the normal tissue planes that are used for dissection, and anatomic relationships are often altered and obscured by fibrosis. The incidence of permanent RLN injury in thyroid and parathyroid reoperations has been reported to range from 2 to 12%.2 In contrast, the incidence of permanent RLN injury during primary thyroid and parathyroid operations is only 0 to 3%.2,3

An enlarged thyroid secondary to a goiter or neoplasm can displace the RLN and make it difficult to locate. The presence of an anatomic variability or anomaly—such as a nonrecurrent laryngeal nerve (estimated incidence: 0.4%) or functional medial RLN branches—can also increase the risk of RLN injury. Other risk factors include malignancy and reoperation for hemorrhage.4,5 In sclerosing thyroiditis (Riedel’s thyroiditis), which is characterized by progressive infiltrative spread, surgical dissection is made difficult by the infiltrative fibrotic nature of the thyroid. Finally, dissection can be complicated in cases when the thyroid is adherent to surrounding structures, including the nerves and vessels in other inflammatory or infectious conditions (e.g., following a tracheotomy).

**EBSLN injury.** EBSLN injury can result in changes in voice quality and increased aspiration.6 Symptoms include easy voice fatigue, difficulty with high pitch, and diminished range. Changes secondary to EBSLN injury are more subtle than those seen in RLN injury, but they may be noticed by professional voice users. EBSLN injury can lead to an alteration of the physiologic frequency range and an inability to sustain a particular pitch. The consequences can be disastrous for singers, actors, and others who rely on their voice for their livelihood.

The position of the EBSLN is variable, and the nerve is not always located and identified during surgery. The estimated rate of injury to the EBSLN during thyroid surgery ranges from 5 to 28%.6 Treatment of injury to this nerve is very difficult.

Stojadinovic et al undertook a prospective study of voice assessments in 54 patients who underwent thyroid surgery.6 At the 1-week follow-up, changes in objective voice measurements were seen in 84% of evaluable patients. At 3 months, 14% of evaluable patients still had voice complaints. Only 1 patient exhibited obvious laryngoscopic evidence of EBSLN dysfunction, but EMG was not performed in this study. No patient exhibited objective findings of RLN palsy. The results of this study emphasize that postoperative voice symptoms are common, but only a fraction of them are attributable to RLN weakness.

Theтhe тtanic тourse of the EBSLN can be variable, and it may be altered by the size and pathology of the thyroid. The EBSLN separates from the vagus nerve via the superior laryngeal nerve approximately 4 cm above the bifurcation of the common carotid artery.7 The EBSLN then descends along the larynx and crosses dorsally to the superior thyroid artery. In 42 to 62% of patients, the EBSLN crosses behind the superior thyroid artery 2 cm or more cephalad to the superior pole of the thyroid gland.7 In 11 to 27% of patients, the distance is less than 2 cm.7 In 13 to 14% of patients, the EBSLN passes behind the superior lobe of the thyroid gland.7 In 13% of patients, the EBSLN does not cross the thyroid artery at the trunk but runs dorsal to the artery until it has ramified.7 In patients...
with an enlarged thyroid gland secondary to a goiter or neoplasm, the reported proportion of EBSLNs that cross less than 1 cm or below the superior pole of the thyroid is as high as 78%. The greatest danger to the EBSLN occurs when the superior thyroid vessels are ligated during dissection of the upper pole of the thyroid.

**Nerve monitoring.** RLN and EBSLN location and preservation techniques include intraoperative electrophysiologic monitoring by surface or needle electrodes, direct observation of the vocal folds via fiberoptic or direct laryngoscopy, and recording muscle contraction and nerve integrity with a nerve monitor. We monitored the RLN with two instruments—either a surface electrode plate or the NIM-2 EMG-equipped endotracheal tube. EBSLN monitoring was achieved by placing and suturing needle electrodes into the cricothyroid muscle. An electrophysiologist was present throughout all 4 of the operations reported herein. We feel that surgeons who are familiar with the NIM-2 nerve monitoring system should be comfortable enough with using the endotracheal tube and cricothyroid electrodes that the assistance of a neurophysiologist is not necessary.

**Electrode plate.** For RLN monitoring, the surface electrode plate is placed over the postcricoid laryngeal surface by the surgeon shortly after intubation. Electrode plate function can be assessed by the NIM-2 monitor or by an electrophysiologist.

**Endotracheal tube.** The other method of RLN monitoring involves the use of an NIM-2 EMG endotracheal tube, which is a cuffed silicone device that is equipped with bilateral stainless steel wire electrodes (figure 1). These electrodes, which run the length of the tube, are exposed to the glottis, and they are capable of recording bilateral vocal fold movement. The electrodes are connected to the NIM-2 facial nerve monitor that tracks EMG activity continuously. The NIM-2 monitor is also equipped with a built-in nerve stimulator that enables direct stimulation of an exposed nerve and subsequent recording of the muscle activity. Electrode position is monitored by electrode impedance values. We have found the EMG-equipped endotracheal tube to be reliable and simple to use. After inserting the tube, the surgeon should ensure that it is placed so that the electrodes are in contact with the glottis. We prefer the endotracheal tube to the postcricoid electrode plate because it is easier to place.

The clinical impact of monitoring in terms of preventing injury to the RLN has been explored in several nonrandomized trials. In one study, Thomusch et al prospectively analyzed 4,382 thyroid operations with and without nerve monitoring in multiple centers. They found that patients who underwent intraoperative neuromonitoring had significantly lower rates of transient and permanent RLN injury (1.4 and 0.4%, respectively) than did patients who did not (2.1% and 0.8%).

**Needle electrodes.** For EBSLN monitoring, needle electrodes are placed into the cricothyroid muscle and sutured into place (figure 2). An electrophysiologist can monitor the electrodes throughout the operation and report any activity...
ELECTROPHYSIOLOGIC LARYNGEAL NERVE MONITORING IN HIGH-RISK THYROID SURGERY

Advantages of monitoring. Nerve monitoring offers the surgeon several advantages during difficult dissection. First, prolonged pressure or stretch on a nerve during retraction can cause a neuropraxic injury and temporary hoarseness; monitoring can detect neural discharge during retraction (figure 3). Second, nerve position and identification can be confirmed by using the surgical nerve locator. Use of the nerve stimulator can be used to distinguish a nerve from a fibrous band (to prevent axonotmesis) and to ascertain the status of the nerve after a stretch or thermal injury.

Thomusch et al analyzed the reliability of intraoperative neuromonitoring signals in thyroid surgery for predicting RLN dysfunction in 15,403 nerves. They found that an intact stimulation signal was 99.6% accurate in predicting normal postoperative nerve function. However, they also reported that an altered stimulation signal does not predict RLN dysfunction. Therefore, surgeons can ascertain the integrity of the nerve after dissection with the stimulator. This can provide useful information and reassurance for the patient in the event of postoperative hoarseness.

Disadvantages of monitoring. Drawbacks of monitoring include the need for additional setup time (10 to 15 min), equipment, and expense, as well as the possibility that the electrodes will malfunction. Electrodes can become displaced or yield falsely low readings in areas of fibrotic tissue. Monitoring can also be affected by hoarseness or a previous vocal fold or nerve injury. Fortunately, an electrophysiologist can provide feedback regarding changes in impedance values or electrode dislodgement. Anesthesiologists must avoid using neuromuscular blocking agents in patients during nerve dissection. Finally, the insertion of needle electrodes theoretically predisposes patients to abscess or hematoma formation.

In conclusion, intraoperative electrophysiologic monitoring of the RLN and EBSLN can be a useful surgical aid during high-risk thyroidectomies. Our 4 cases illustrate circumstances in which nerve monitoring was beneficial to the surgeon.

References