The Use of Readily Available Equipment in a Simple Method for Intraoperative Monitoring of Recurrent Laryngeal Nerve Function During Thyroid Surgery

Initial Experience With More Than 300 Cases

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Hypothesis: An inexpensive and widely applicable technique to monitor recurrent laryngeal nerve (RLN) function during thyroid surgery can be safely implemented.

Design: Consecutive sample.

Setting: Single-surgeon academic practice.


Interventions: Anesthetic management using laryngeal mask airway and spontaneous ventilation, combined with electrical RLN stimulation and fiberoptic video laryngoscopy to confirm vocal cord response.

Main Outcome Measures: Vocal cord response to RLN stimulation, intraoperative anatomic findings, postoperative voice quality, and anesthetic complications.

Results: We used the laryngeal mask airway–based technique in 327 cases. Visualization of vocal cords was maintained throughout the surgery in 310 cases (95%). In 10 cases (3%), the branch of the RLN carrying vocal cord function could not be identified until electrical testing was performed. A single inadvertent RLN palsy was seen in 1 of the 17 cases in which vocal cord visualization was lost during the procedure (0.03% overall). Upper airway obstruction occurred in 16 (5%) of 327 attempted procedures, requiring tracheal intubation in 3 (1%). No further complications regarding airway management were seen. Pneumothorax was observed in 5 cases (2%), each of which resolved without chest tube placement.

Conclusions: This technique can be applied to thyroid surgery as a safe means of managing the airway. It is associated with an ability to test RLN function at will in more than 95% of cases using readily available equipment.

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A major morbidity associated with thyroid surgery is injury to the recurrent laryngeal nerve (RLN) within the field of dissection. Wagner and Seiler reported an incidence of RLN injury of 5.9%, with a rate of permanent vocal cord paralysis of 2.4% in a series of 1026 cases of thyroid surgery. Poor voice quality and the potential for recurrent tracheal aspiration result. To reduce the incidence of RLN injury, several techniques to monitor RLN function during thyroid surgery have been described. Most are based on electrical RLN stimulation with committed monitoring devices, such as special endotracheal tubes or electrodes (Neurovision SE; RLN Systems, Inc, Jefferson City, Mo) and additional out-of-field personnel to monitor the results of stimulation on an oscilloscope or similar readout device.

The laryngeal mask airway (LMA) has also been used to help monitor RLN function during thyroid surgery. A flexible fiberoptic bronchoscope can be introduced through the LMA to obtain a view of the larynx. Fiberoptic visualization of vocal cord movement can confirm RLN integrity during electrical stimulation by the surgeon using a sterile nerve stimulator. This technique allows for monitoring of RLN function using equipment that is readily available in every operating room, and thus eliminates the need for purchase of further monitoring equipment or the expense of specially trained personnel. The bronchoscope can also be connected to a video camera, allowing for projection of the obtained image on a video screen using equipment widely available for laparoscopic surgery.

Hobbiger et al used the LMA in 97 cases of thyroid and parathyroid surgery. Nerve stimulation was performed in only 50% of cases; therefore, no conclusion regarding the overall success rate of this...
SUBJECTS AND METHODS

SUBJECTS

All patients undergoing surgery for thyroid disease by a single surgeon (F.D.M.) at our institution from November 1, 1999, through May 31, 2001, were included in an analysis in which all data were collected prospectively. We reviewed 363 consecutive cases. In 327 cases, the LMA-based technique was used.

ANESTHETIC MANAGEMENT

Intravenous access was obtained preoperatively, and most patients received intravenous midazolam hydrochloride (0.5-2.0 mg). After placement of electrocardiographic and noninvasive arterial blood pressure and oxygen saturation monitors, anesthesia was induced using propofol, 1.5 to 4.0 mg/kg, and an LMA No. 3 to No. 5 (LMA North America, Inc, San Diego, Calif) was inserted. If tracheal occlusion during the surgery seemed likely, an intubating LMA 3-5 was used alternatively. Patients were kept anesthetized by means of desflurane or sevoflurane in a mixture of nitrous oxide and oxygen with spontaneous ventilation. Use of intraoperative narcotics was limited purposely by using intravenous ketorolac tromethamine (30 mg) and injection of 0.25% bupivacaine hydrochloride into the wound before incision. All patients received intravenous antemetic prophylaxis with ondansetron hydrochloride (2-4 mg), metoclopramide hydrochloride (10 mg), and injection of 0.25% bupivacaine hydrochloride (10 mg), or droperidol (0.6 mg) before emergence from anesthesia.

MONITORING OF RLN FUNCTION

When monitoring of the RLN was desired, a pediatric fiberoptic bronchoscope (LF-GP PortaView Intubation Scope; Olympus, San Jose, Calif) was advanced over a swivel adaptor (Portex, Inc, Keene, NH) through the LMA into the larynx, allowing visualization of the vocal cords. The image was displayed to the surgical team on a video monitor after connecting the bronchoscope to a video camera designed for video laparoscopy. The surgeon stimulated the RLN using a sterile nerve stimulator (Varisistim III Surgical Nerve Locator; Xomed, Jacksonville, Fla) set at 0.5 to 2.0 mA, according to the minimum amount of current required to produce twitching in exposed superficial neck muscle fascicles. Correct identification and intact RLN function were confirmed by observing unilateral vocal cord motion on stimulation.

SURGICAL TECHNIQUE

All operations were performed with loupe magnification. After initial general thyroid mobilization, the upper pole was taken down, and vessels were divided directly on the surface of the thyroid to avoid the external branch of the superior laryngeal nerve. At this point, the upper portion of the thyroid lobe was rotated down and medially, exposing the ligament of Berry. After mobilization of the upper parathyroid gland, the RLN was identified lateral to the ligament and within 5 mm of entry into the larynx. Gentle dissection was performed in a more medial direction to discover any more medial branches, after which the nerve and its branches were gently swept to the side, away from the thyroid. At this point, the nerve was tested with the electrical stimulator. If the RLN and its branches were found not to function, then dissection was performed proximally along the identified nerve segment to discover additional occult branches (which then underwent testing).

SUBJECT CHARACTERISTICS

We included 363 consecutive patients undergoing surgery for thyroid disease. Patient demographic data are described in the following tabulation:

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<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMA/endotracheal intubation</td>
<td>327/36</td>
</tr>
<tr>
<td>Male/female</td>
<td>67/296</td>
</tr>
<tr>
<td>Thyroid carcinoma</td>
<td>184</td>
</tr>
</tbody>
</table>
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The patients were predominantly middle-aged (mean ± SD age, 47±14 years) and female (82%). In 51% of the cases, a final diagnosis of carcinoma of the thyroid was made. Surgical procedures are tallied in the following tabulation for the 327 patients in whom the LMA was used:

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<table>
<thead>
<tr>
<th>Surgery</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyroid lobectomy</td>
<td>111</td>
</tr>
<tr>
<td>Completion thyroidectomy</td>
<td>31</td>
</tr>
<tr>
<td>Near-total thyroidectomy</td>
<td>12</td>
</tr>
<tr>
<td>Total thyroidectomy</td>
<td>147</td>
</tr>
<tr>
<td>Total thyroidectomy and node dissection</td>
<td>12</td>
</tr>
<tr>
<td>Reoperative paratracheal dissection</td>
<td>8</td>
</tr>
<tr>
<td>Debulking</td>
<td>1</td>
</tr>
<tr>
<td>Internal jugular node dissection</td>
<td>2</td>
</tr>
<tr>
<td>Subtotal thyroidectomy</td>
<td>3</td>
</tr>
</tbody>
</table>
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Considering that an internal jugular node dissection does not directly expose the RLN, and that bilateral thyroid surgery exposes the RLN on each side, 501 RLNs were put at risk during this series.

AIRWAY MANAGEMENT

In 327 of the 363 cases, the LMA was used as the airway. Of the 36 cases in which the LMA technique was not used, tracheal intubation was elected in 11 owing to anticipated intraoperative tracheal occlusion if the stenting effect of the endotracheal tube was not present. In 6 cases, the use of the LMA was contraindicated (severe gastroesophageal reflux disease, pregnancy, and...
The lateral branch anastomosed with an adju-

The injured RLN branched inferior to the lower pole of

scope placement. In this group, the only inadvertent RLN

to much airway motion to allow for accurate broncho-

ment issues described above and an additional case with

of the 327 cases, ie, the 16 cases with airway manage-

sualization of the vocal cords could be achieved (Figure).

Functional Branch Discovered Only by Results of Testing 10 (3%)

Branching of RLN Proximal of Inferior Thyroid Artery 56 (18%)

Total No. of Cases 363

Tracheal Intubation 36

LMA 327

Direct Visualization Successful 327 (100%)

Visualization Maintained 310 (95%)

Secondary Loss of Visualization 17 (5%)

Nerve Stimulation Effective 274 (88%)

Nerve Stimulation Effective in 1 of 2 Nerves 22 (7%)

No Vocal Cord Movement on Stimulation 14 (5%)

RLN Palsy 1 (0.3% of All Cases)

Use of the laryngeal mask airway (LMA) in combination with fiberoptic visualization of the vocal cords to monitor recurrent laryngeal nerve (RLN) function during thyroid surgery. Of 363 cases, the LMA could be used in 327, allowing visualization of the vocal cords throughout the surgery in 310 cases. In 10 cases, only results of testing could identify the branch of the RLN carrying vocal cord function. In the whole series, 1 case of inadvertent RLN paralysis was observed among 17 patients in whom visualization of the vocal cords was lost during surgery. morbid obesity), and in 1 case, the patient preferred tracheal intubation. In 5 cases, the staff anesthesiologist was unfamiliar with the technique. In 11 cases, the surgery was deemed not to put the RLNs at risk. In 1 case each, an LMA device was not available, and the patient required endotracheal intubation for another simultaneous procedure. No patients in this group sustained an RLN injury.

In 16 cases (5%) in which the LMA was used, upper airway obstruction occurred during surgery. Fiberoptic examination of the larynx showed supraglottic edema in 5 cases that resolved on changing the patient’s head position from extension to neutral. In 11 cases, true laryngospasm was seen, requiring a subintubating dose of succinylcholine chloride in 5, tracheal intubation in 3, and an increase in the depth of anesthesia in 3. Minor degrees of laryngospasm, particularly during dissection of the upper poles of the thyroid, were common. No other complications related to airway management were reported.

**RLN ANATOMY**

Branching of RLN between the inferior thyroid artery and the larynx, usually within 5 mm of the larynx, was common and not tallied in this study. Branching of the RLN proximal to the inferior thyroid artery was seen in 56 cases (15% of all cases), with performance of vocal cord function by the medial branch in 46 (82%) of these. In 4 cases (7%), the function was performed by the lateral branch. In 6 cases (11%), vocal cord function was performed by a medial branch on one side and by a lateral branch on the other side. In 10 cases (3% overall), the branch performing vocal cord function was not identified until electrical stimulation was performed and failed, and further dissection discovered a more medial, functional branch.

**SAFETY**

In 5 cases, pneumothorax was suspected clinically owing to mild hypoxemia and was documented on the postoperative chest x-ray film. All 5 cases were treated with thoracentesis alone. In 4 of these cases, patients had had prolonged but moderate upper airway obstruction. Two of the cases included internal jugular node dissections reaching below the clavicles. A single case sustained no element of obstruction and was a thyroid lobectomy, apparently well above the limits of the pleura.

**COMMENT**

To reduce the rate of RLN injury in patients undergoing thyroid surgery, several techniques to monitor RLN function have been described. Most rely on electromyographic (EMG) recordings derived from the laryngeal musculature after stimulation of the RLN with electrical
current.2-6 These techniques are associated with additional costs for initial purchase of monitoring devices, ongoing purchase of electrodes, and salary and training for personnel to read the monitors during surgery. In addition, lost electrical contact of the electrodes and the use of muscle relaxation are potential sources of error. We describe herein the use of the LMA during spontaneous ventilation to allow monitoring of RLN function by means of fiberoptic visualization of vocal cord movement during electrical stimulation. This simple technique avoids the use of muscle relaxation and can be performed with equipment that is readily available in most operating suites. The LMAs are not disposable and are used for many procedures in addition to our application. Flexible fiberoptic bronchoscopes are in wide use by departments of anesthesia, thoracic surgery, and otolaryngology. The video cameras and monitors are the same as those used for laparoscopic surgery. In this series of 363 thyroid surgeries, the technique could be applied in 327 cases and was associated with an ability to monitor RLN function at will in 95% of cases throughout the surgery, resulting in a single case of proven RLN injury.

This series of cases arose from the desire by one us (F.D.M.) to understand an ongoing 1% to 2% rate of RLN injury during thyroid surgery, despite universal systematic identification and preservation of the RLN. This rate of injury is comparable to that of many reports.1,10,12 The lowest rate was that of the Lahey Clinic report of 1971,10 in which a 0.14% rate of injury was reported and the argument was advanced that the RLN should always be identified. Most groups, however, currently report 2% to 4% rates of RLN injury. Some authors14-16 have emphasized the nonrecurrent RLN as a potential source for this continuing rate of injury, an anatomic variant occurring at a low rate and putting the RLN at risk early in the dissection. The results of all of these studies were based on dissection data, not on functional data. In this report, we described variation of RLN anatomy (15% of cases) and combine these data with results of functional assessment. Our demonstration of the variation in RLN functional anatomy may explain current rates of injury. Despite awareness of and a systematic search for more medial branches of the RLN after initial nerve identification, we report herein a 3% rate at which an undetected, functional, more medial RLN branch was revealed only through results of the electrical testing. We also found a rate of inconsistency, with the functional RLN being the medial branch on one side of the neck and the lateral branch on the other side in 6 cases (2% overall). Inadvertent injury to these functional, medial branches of the RLN when undetected would account for the current rates of RLN injury. Systematic application of techniques, such as that outlined herein, may allow the surgeon to identify and spare these portions of the RLN. The single RLN injury reported in this series was the result of such an anatomic variant and occurred during a case in which the LMA-bronchoscopic monitoring system failed. The rate of RLN injury was unlikely to be higher than that reported, given the few additional cases of transient hoarseness and the previous reports that the surgeon’s judgment on the presence or absence of RLN injury after surgery is highly accurate.12 Whether to implement such a system depends on issues of efficacy and safety, as well as cost.

Not all cases can be managed with spontaneous ventilation and an LMA. Contraindications involve associated conditions and anticipated anatomic constraints. The LMA is not indicated for patients with severe gastroesophageal reflux disease, as protection of the airway from aspiration is not as good as with endotrachael intubation. The amount of positive pressure that can be applied to assist ventilation in LMA is 20 mm Hg, making it difficult to assist ventilation in patients with severe obesity or advanced pregnancy during surgery. In certain cases, such as a fixed malignancy, entry into the trachea for purposes of resection would require an endotrachael tube. In others, such as a substernal goiter with airway compression, one should be concerned with complete airway occlusion of the unstented trachea during initial mobilization. This technique is pointless in cases where the RLN is not at risk, such as a jugular node dissection. Finally, not all anesthesiologists are secure in the techniques of general anesthesia with the LMA device. In our hands, the technique was used in 90% of thyroid cases, among which we would expect a maximum of 95% of cases to be eligible, given the rate of contraindications.

Even when this anesthesia technique is implemented, it may not be possible to visualize a response of the vocal cords to electrical stimulation. Anesthesia and airway management with this technique can be difficult. We found a 5% rate of upper airway obstruction during surgery that required intervention. Some cases required endotracheal intubation, meaning that neuromuscular relaxation was used as well as an airway that precluded visualization of vocal cords. Most of these cases were due to supraglottic edema or laryngospasm. Supraglottic edema appears to occur as a result of the extended neck position for surgery plus the LMA inflation. We currently avoid this complication by using a more neutral position of the neck for surgery. Laryngospasm is due to an insufficient level of anesthesia and almost always occurs during dissection of the upper pole. It is preventable with adequate depth of anesthesia and can be treated effectively with a subparalyzing dose of succinylcholine combined with assisted ventilation. Also, with the LMA in place and the bronchoscope obtaining excellent visualization, electrical stimulation might elicit no response. The main issue in such a situation is that the functional portion of the RLN has not been identified. However, the nerve stimulator may not be functioning. For this reason, we now test the battery on the device and then test the stimulus directly on exposed laryngeal musculature for muscle twitching before applying it to the nerve. Since implementing this refinement, the issue of never being able to elicit a response has disappeared. An RLN may also be injured when electrical testing is overzealous, possibly the cause for the cases of transient hoarseness that we have seen. Despite these issues, we were able to test all of the exposed RLNs in a given case at will in 88% of our cases. As we have gained more experience, our rate of efficacy in maintaining visualization and then attaining vocal cord response to stimulation is nearing 100%.

The upper airway occlusion issues also have an impact on the safety of this technique. One is well advised
to use a single experienced anesthesiologist to introduce this method into a thyroid surgery practice. We also encountered 5 cases of pneumothorax, which is an unusual problem. None was life threatening, and all could be treated with simple aspiration. We theorize that pneumothorax was caused by breach of the apex of the pleura in the neck, combined with the negative pressure of spontaneous ventilation. This is clearly the case in the 2 jugular node dissections, which were performed below the clavicles. The case that we cannot readily explain was the thyroid lobectomy in a young woman with a long neck, in which there was no dissection close to the apex of the pleura. Given our experience, we obtain chest radiographs for unexplained episodes of oxygen desaturation during surgery or in the recovery room.

The major alternative to this technique uses conventional endotracheal anesthesia and EMG readout of function. This requires placement of EMG electrodes on the endotracheal tube or directly in or on the larynx during surgery, combined with electrical nerve stimulation and an oscilloscope-type monitor with a technician to report the results. Endotracheal tubes with integrated electrodes are also commercially available. Newer systems use integrated circuits and an alarm to indicate when the nerve has been stimulated, eliminating the technician. We anticipate that this technique would give equivalent intraoperative results to those that we are reporting and would be usable in all patients. In terms of ultimate advantage to the voice, one also must consider the injury that an endotracheal tube can cause to the vocal cords. The advantage to our technique is its simplicity and lack of additional capital cost, leading to its accessibility to surgeons in all types of practice settings.

Attempts to use LMA-based anesthesia in combination with fiberoptic demonstration of movement of the cords have been described before. The only published systematic evaluation of this technique was performed in patients paralyzed with 0.1 mg/kg of vecuronium bromide. Nerve stimulation was performed only on request of the surgeon or for educational reasons; thus RLN monitoring was performed in less than 50% of cases. Therefore, that study did not allow conclusions concerning the number of patients in whom the technique could be used successfully. The present study demonstrates that the LMA, in combination with fiberoptic visualization of the vocal cords, has a success rate of monitoring RLN in more than 95% of cases when the LMA is used. In association with this ability to monitor nerve function, 3% of cases were found to have RLN anatomy particularly prone to injury. This was recognized and avoided, with a resulting incidence of inadvertent RLN palsy of 0.3%, which is lower than that reported in most large series.

This paper was presented at the 82nd Annual Meeting of the New England Surgical Society, Providence, RI, September 23, 2001.

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REFERENCES


DISCUSSION

Walter B. Goldfarb, MD, Portland, Me: The RLN has been of more than passing interest to thyroid surgeons since the beginning of thyroid surgery, and it has been the bête noire and of particular interest to New England surgeons, especially since the landmark paper of Dr Lahey in 1938, and again in 1944, advocating exposure of the RLN in all cases of thyroid surgery to avoid inadvertent injury. Since then, the role of the RLN in thyroid surgery has received a great deal of extended attention and the anesthesiologist is required for success. The 10 cases (3%) or so that were found to have an anomaly which would have resulted in injury had this not been done, as Dr Moore
pointed out, I think attests to the utility and the excellence of this technique.

What about the large goiters, the substernal goiters, and those with tracheal deviation or tracheal narrowing? Do you advise monitoring the nerve in all thyroidectomies and, for that matter, all parathyroidectomies? You noted 17 instances of bilateral surgery and only 1 nerve function monitoring, and in 14 no movement of either cord was noted on stimulation, with no injury, it might be added. What do you do when there is no response? How long do you persist in stimulating the nerves? Obviously there has to be a learning curve between the anesthesiologist and the surgeon, and I have given a copy of your manuscript to our anesthesiologist to see if we can start doing this.

This presentation sets a new standard, and I commend you for this major contribution. I would like to close by showing a slide or two of historic interest with reference to the RLN. Sex, Surgery, Treasure and Travel is the autobiography of George Crile, Jr, and that is the picture—the expanded picture shows 15 people surrounding the operating table in street clothes, and on the right is George Crile, Sr, helped by his son, Barney, doing his 25000th thyroidectomy. This is 1936, 2 years before Dr Lahey's major article on exposure of the nerve.

Dr Crile, Jr, had just come to The Cleveland Clinic and said:

My father of course was delighted to have me back and by now he really needed me. His eye sight was so deteriorated to the point that he could not read, drive or even walk without stumbling over things. Yet, he was still doing 5 to 6 operations a day, mainly thyroidectomies and adrenal denervations, and these he was doing almost entirely by sense of touch. The resident would make the incision, expose the gland, and then my father would step in and denervate or remove whatever was necessary and the resident would close.

He goes on to say that:

Thyroid surgery was not so bad. Since my father had never done an anatomical operation with identification of the recurrent laryngeal nerves or the parathyroid glands—this is 25000 by 1936—the results were not much worse than before, and so long as there was not any extensive cancer to deal with, no serious accidents occurred.

Well, I think we have come a long way from this.

Thomas Colacchio, MD, Lebanon, NH: Chip, I am just wondering if you could tell us about how long this adds to your surgical procedure in terms of the manipulation, and give us a sense of what the anesthetic and airway management was in those patients for whom you had the difficulties with subglottic edema and laryngospasm.

Roger Foster, MD, Shelburne, VT: There are periodically reports of idiopathic vocal cord dysfunction, and people have explained that as similar to Bell's palsy. Is that simply an excuse for an undocumented nerve injury, or have you encountered this in your screening of vocal cord function prior to any surgical dissection?

Harold Wanebo, MD, Providence, RI: I am just reminded of an article by Katz a few years ago describing the branching of the recurrent nerve, and there was some suggestion, as you mentioned, that the—with the branches—you described the medial branch, which appears to be not easily described, I guess, by dissection. The question is, do you have some idea about the functional aspect of these—whether they are adductor, abductor—when your anesthesiologist was working with you?

Dr Moore: I will say that the all-time lowest recurrent nerve injury rate reported was from the Lahey Clinic in the 1950s and 1960s and was 0.1%. It was contained in a large series which advocated exposure of the recurrent nerve to prevent injury.

In terms of Dr Goldfarb’s questions, I currently do avoid this technique where I think I am going to occlude the trachea during the surgery. As we have gained more experience, we have gotten more aggressive with it. To attempt to use this with an endotracheal tube in place means that an anesthesiologist is going to have to place a laryngoscope and reproduce the original intubation to get enough space in the pharynx to get a view of the vocal cords with the scope.

The article in The Wall Street Journal reported a simplified computerized device that has an electrode that goes onto the larynx and then has an output which is either dissecting scissors or a probe. An alarm goes off every time a signal comes in through the electrode. Many of you have probably seen it advertised. The problem, of course, is that 1 case of mine with the recurrent nerve injury is one where the electrode clearly would have registered an EMG signal despite the fact that the nerve being tested was not the actual adductor branch.

In response to Dr Wanebo, I think, actually, the medial branch is fairly well described. The prevalence of them is not quite so well appreciated, and when they do function it is always adductor.

I do not use this during parathyroid surgery. For whatever reason, I have always felt that parathyroid exploration did not require very much cutting down near the nerve, even though parathyroid adenomas are virtually always adjacent to the nerves.

If I get no response from the stimulation, I will dissect more medially underneath the thyroid, and I am not going to persist with the stimulation excessively, being concerned about injuring the nerve with the electric current. If I am really completely dissecting out the area, find no medial branch, and have no response, I will just go ahead and complete the surgery.

The length of time this adds in total is probably a negative number, because once you are conversant with the technique, expose the nerve, and see that the nerve functions right in the area where you are going to be dissecting it, that is the end of the problem. You can simply go on to conclude the case.

The difficult airway management is more problematic. We will put out a companion piece on the next 100 cases in the anesthesia literature describing this more thoroughly. The positioning is key. You cannot use the standard hyperextended position. The depth of anesthesia is key. If the patients are light at all and you get to the upper poles, they will start to have laryngospasm. We needed to change to endotracheal intubation in about 10 of these cases over this time.