Recurrent Laryngeal Nerve Monitoring During Thyroidectomy and Related Cervical Procedures in the Pediatric Population

W. Matthew White, MD; Gregory W. Randolph, MD; Christopher J. Hartnick, MD; Michael J. Cunningham, MD

Objectives: To gather data on, and assess the applicability of, intraoperative recurrent laryngeal nerve (RLN) monitoring during thyroidectomy and related cervical procedures in children and adolescents. Recurrent laryngeal nerve trauma is one of the most serious complications of surgery in the anterior neck compartment. Numerous studies have demonstrated the utility of intraoperative monitoring of the RLN in adult thyroid surgery to prevent such injury. Although the risk of RLN injury is reportedly higher in the pediatric population, little data exist regarding the use of intraoperative RLN monitoring in children and adolescents.

Design: Retrospective case series review.

Setting: A pediatric otolaryngology practice in a tertiary care hospital.

Patients: Five patients undergoing surgical excision of thyroid neoplasms or branchial pouch anomalies.

Interventions: During surgical excision, intraoperative RLN monitoring was performed with use of the Xomed NIM II monitor and Xomed RLN monitoring endotracheal tube, which allow for both passive and stimulation-evoked electromyographic monitoring of the thyroarytenoid muscle.

Main Outcome Measures: True vocal fold mobility as assessed by postoperative flexible laryngoscopy.

Results: Intraoperative RLN monitoring was performed successfully for up to 4 hours. Such monitoring facilitated the identification of the RLN and was predictive of the subsequent presence or absence of postoperative RLN paresis.

Conclusions: Intraoperative RLN monitoring can be a useful tool during cervical procedures that place the RLN at risk in children and adolescents. As has been demonstrated in adults, it is a safe and reliable technique that can be predictive of and may lessen the risk of RLN morbidity in this younger patient population.


Injury to the recurrent laryngeal nerve (RLN) is an infrequent but major complication of thyroid surgery.1 Manifestations include paralytic dysphonia and dysphagia, paroxysmal coughing, airway obstruction, and aspiration, all of which contribute to significant postoperative morbidity.

Intraoperative monitoring of RLN function during thyroid surgery has been extensively used in adult patients and has been found both useful and effective in reducing the risk of RLN paralysis.2,3 Intraoperative nerve monitoring appears to be especially applicable in cases with increased risk of morbidity from RLN paralysis such as patients who have undergone previous neck surgery, surgery on the side of a remaining functioning RLN, thyroidectomy for Grave disease, thyroidectomy for large cervical or substernal goiters, surgery after radiation therapy or radioactive iodine treatment, and in cases where bilateral thyroidectomy or bilateral paratracheal dissection is planned and therefore injury to both RLNs is possible.

Thyroidectomy is a much less common procedure in the pediatric population. The primary indication is a thyroid mass confirmed or suspected to be malignant. There are, however, other surgical procedures of the neck and upper chest more frequently performed in children that also place the RLN at potential risk. These include ligation of a patent ductus arteriosus and, of relevance to pediatric oto-

Author Affiliations:
Department of Otolaryngology, Massachusetts Eye and Ear Infirmary, and Department of Otolaryngology, Harvard Medical School, Boston, Massachusetts.
laryngology, the excision of branchial pouch anomalies. The altered neck anatomy that may occur with branchial pouch anomalies due to the developmental anomaly itself or secondary infection further complicates RLN identification, increasing the risk of injury. Based on the demonstrated safety, utility, and reliability of RLN monitoring in adults undergoing thyroid surgery at our institution, we elected to assess the applicability of this technique in selected pediatric operations.

METHODS

This retrospective case series involves 5 patients over the course of 1 year who required surgical intervention for either a thyroid mass or a branchial pouch anomaly potentially involving the thyroid gland (Table 1). Intraoperative RLN monitoring was performed with the use of the Xomed NIM II monitor (Medtronic Xomed, Jacksonville, Florida), and the Xomed NIM monitoring endotracheal tube with surface electrodes designed to rest on the luminal aspect of the bilateral true vocal cords (Figure 1). This system allows the documentation of both passive and evoked electromyographic (EMG) monitoring of the thyroarytenoid laryngeal muscle during surgery. When positioned correctly, the electrodes can detect baseline respiratory variations and characteristic EMG waveforms of electrically evoked RLN responses. Correct endotracheal tube positioning is typically straightforward when a placement algorithm is followed. General anesthesia must be administered without the use of muscle paralysis to enable EMG recording. Xomed NIM endotracheal tubes are available in various sizes to fit age-appropriate tracheal airway dimensions (Table 2). The prototype of a smaller tube (inner diameter [ID], 5.0 mm; outer diameter [OD], 7.8 mm) was additionally used in 1 of our 5 cases.

RESULTS

Included in this case report series are 2 female patients (aged 15 and 17 years) with unilateral thyroid masses, 2 patients with recurrent unilateral neck infections secondary to third and fourth branchial pouch sinus tract anomalies (an 11-year-old boy and a 16-year-old girl), and a 15-year-old boy with metastatic papillary thyroid carcinoma (Table 1). In preoperative planning, these patients were selected to undergo intraoperative RLN monitoring owing to the suspected proximity of the ipsilateral RLN to their cervical lesions. Two representative cases are presented in greater detail.

Table 1. Patient Demographics

<table>
<thead>
<tr>
<th>Patient No./ Sex/Age, y</th>
<th>Definitive Diagnosis</th>
<th>Postoperative RLN Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F/16</td>
<td>Fourth branchial pouch anomaly</td>
<td>Normal ipsilateral</td>
</tr>
<tr>
<td>2/M/15</td>
<td>Metastatic thyroid papillary carcinoma</td>
<td>Normal left; paretic right (transient)</td>
</tr>
<tr>
<td>3/F/15</td>
<td>Thyroid follicular adenoma</td>
<td>Normal ipsilateral</td>
</tr>
<tr>
<td>4/M/11</td>
<td>Third branchial pouch anomaly</td>
<td>Normal ipsilateral</td>
</tr>
<tr>
<td>5/F/17</td>
<td>Thyroid follicular adenoma</td>
<td>Normal ipsilateral</td>
</tr>
</tbody>
</table>

Abbreviation: RLN, recurrent laryngeal nerve.

Table 2. Endotracheal Tube Sizes With Recommended Appropriate Age Ranges

<table>
<thead>
<tr>
<th>Tube Size, ID/OD, mm</th>
<th>Age, y</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0/7.8</td>
<td>10-12</td>
</tr>
<tr>
<td>6.0/8.8</td>
<td>13-15</td>
</tr>
<tr>
<td>7.0/9.8</td>
<td>16-18, older adolescent girl or woman</td>
</tr>
<tr>
<td>8.0/10.8</td>
<td>16-18, older adolescent boy or man</td>
</tr>
</tbody>
</table>

Abbreviations: ID, inner diameter; OD, outer diameter. *Prototype investigative endotracheal tube.

CASE 1

A 16-year-old girl presented with a 6-month history of recurrent tender left neck swelling. Over this time period she had 3 admissions to an outside institution with radiographic confirmation of a perithyroidal left neck abscess. Computed tomographic scans performed during prior acute presentations showed extensive soft-tissue changes consistent with left neck abscess adjacent to the left thyroid lobe (Figure 2A and B). Despite prior interventions including computed tomographic needle-guided drainage, intravenous antibiotic therapy, and left neck exploration with drain placement, left neck swelling continued to recur.

On physical examination she was found to have pericervical erythema with palpable mild swelling and minimal tenderness superior to her previous cervical incision; no additional neck masses or lymphadenopathy were noted. Results of a barium swallow study (Figure 2C) suggested the presence of a tract arising from the apex of the left piriform sinus consistent with a branchial pouch anomaly. A preoperative magnetic resonance image dem-
onstrated some increased soft-tissue density adjacent to the left piriform sinus and left thyroid lobe but did not suggest residual abscess. At endoscopy an opening at the apex of the left piriform sinus was identified (Figure 2D) and cannulated with an embolization catheter. Concurrent left neck exploration revealed extensive postinflammatory soft-tissue scarring adjacent to the left lobe of the thyroid gland and superficial to the carotid sheath. A tract was clearly identified in the region of the cricothyroid membrane contiguous with the apex of the left piriform sinus; palpation of the embolization catheter confirmed it to be the previously identified sinus tract. Scarified strap musculature associated with the previous abscess cavity was excised along with the suspected sinus tract, the latter ligated at its base. Ipsilateral hemithyroidectomy eventually proved necessary for complete lesion excision.

The RLN was identified in its expected position in the tracheoesophageal groove coursing to the laryngeal entry point. Monitoring was found useful given the proximity of the RLN to the perithyroidal inflammation and scarring. Intact RLN function was demonstrable on stimulation throughout and at the close of the procedures; a 7.0-mm ID/9.8-mm OD Xomed NIM endotracheal tube was used. Postoperative awake flexible laryngoscopy confirmed normal bilateral true vocal fold mobility.

CASE 2

A 15-year-old boy presented with a 2-month history of a slowly progressive, nontender left neck mass. He had no dysphonia or dysphagia. Physical examination revealed prominent left cervical lymphadenopathy, the largest of which measured 1.5 x 2 cm along the posterior-inferior border of the sternocleidomastoid muscle. There was no palpable thyromegaly or right cervical adenopathy. Flexible laryngoscopy findings were normal from both an anatomic and functional standpoint. Contrast-enhanced computed tomography demonstrated a solid soft-tissue mass within the left thyroid lobe (Figure 3A) and isthmus, as well as extensive paratracheal and left cervical (levels 3 and 4) lymphadenopathy (Figure 3B). Fine-needle aspiration cytologic findings were consistent with thyroid papillary carcinoma. Thyrotropin, T3, and T4 uptake levels were normal.

A total thyroidectomy, central node dissection, and left modified neck dissection were performed. A 6.0-mm ID/8.8-mm OD endotracheal electrode tube was used for intraoperative RLN monitoring. Despite difficult dissection of the left RLN owing to encasement of the nerve by both the thyroid mass itself and the left paratracheal lymphadenopathy, the left intraoperative EMG signal per-
sisted without change. Both the left and right RLNs were identified and demonstrably intact at the completion of the surgery; however, the amplitude of the EMG response to stimulation of the right RLN was significantly decreased. These intraoperative findings correlated with postoperative awake flexible laryngoscopy findings that revealed intact left true vocal fold function but right true vocal fold paresis. The latter eventually resolved several months thereafter.

**COMMENT**

The anatomy of the RLN has been well described. The vagus nerve courses down the neck from the jugular foramen within the carotid sheath. The RLN typically branches off the vagus at the level of the subclavian artery on the right and at the level of the aorta on the left, delivering general visceral afferents and branchial efferents to the inferior constrictor, cricopharyngeus, and all laryngeal intrinsics except the cricothyroid muscle. Both RLNs ascend along the tracheoesophageal groove entering the larynx just under the inferior edge of the cricopharyngeus muscle at the caudal margin of the cricoid cartilage laterally. Cortical areas of laryngeal representation project to bilateral brainstem nuclei, which in turn project to the ipsilateral larynx. Adductor fibers significantly outnumber abductor fibers; these 2 fiber types have no spatial orientation within the RLN.

Variations in the expected anatomic position of the RLN can occur. The risk of nerve injury increases in patients with anomalous RLN anatomy. Such anomalies include nonrecurrence of the RLN, RLN displacement by thyroid nodularity or paratracheal lymphadenopathy, extralaryngeal branching of the RLN, and variations of the nerve course in relation to the inferior thyroid artery and ligament of Berry. In a recent analysis of RLN anatomy in 491 thyroid surgery cases, 60.8% of RLNs were found in the expected tracheoesophageal groove position, whereas 4.9% were lateral and 28.3% were posterior to the trachea; of greatest concern are those cases where the RLN was found on the anterior surface of the thyroid gland, a particularly high-risk area for nerve injury.

Approximately 10% of all thyroid cancers occur in patients younger than 21 years. All masses within the thyroid gland in a pediatric patient should be considered malignant until proven otherwise. A history of prior radiation exposure further increases the risk of malignant neoplasm. Despite the advanced stage at presentation characteristic of pediatric thyroid cancer, prognosis is typically excellent. Surgical planning must therefore strongly emphasize RLN and parathyroid gland preservation with concurrent complete excision of gross disease of the thyroid and affected cervical nodal compartments.

The reported incidence of RLN paralysis approximated 6% in 1 large series of pediatric thyroidectomy cases. The comparative rate of immediate vocal fold paralysis following thyroidectomy in a high-volume adult thyroid unit was 7% when all patients routinely underwent postoperative laryngoscopy. In children, as in adults, it is essential that prior to thyroid surgery the larynx be examined in all patients. Postoperative laryngeal examinations are highly desirable as well, given the range of vocal changes possible from transient intubation-related hoarseness to impaired true vocal fold mobility from RLN paresis or paralysis.

Pediatric patients are also at risk for RLN injury when surgery is performed in the setting of a cervical embryologic anomaly. Two of our cases are representative of such situations. Third and fourth branchial pouch sinus tracts are rare, accounting for only 1% to 2% of all branchial anomalies. There is a female predominance and a left neck predilection. These branchial pouch anomalies typically present as a cystic cervical mass or perithyroidal abscess; the latter may be misdiagnosed as suppurative thyroiditis. Both third and fourth branchial pouch sinus tracts have expected distinct anatomic relationships relative to the RLN. Such sinus tracts originate within the base (third) or apex (fourth) of the piriform fossa and should course between the superior laryngeal nerve and the RLN. This relationship can be obscured when there is acute inflammation or postinflammatory scarring.

The benefit of intraoperative identification of the RLN during the excision of such branchial pouch anomalies is controversial. Some authors advocate dissection and exposure of the RLN, while others claim that doing so...
places the nerve at increased risk.\textsuperscript{12} The analogous controversy regarding routine RLN identification during thyroidectomy has historically been resolved in favor of routine identification and dissection in all cases regardless of the challenges the operative field may pose.\textsuperscript{1,13}

As noted, it is well established that visual identification of the RLN during thyroid surgery reduces the incidence of iatrogenic RLN palsy.\textsuperscript{1,14} Various intraoperatively methods of monitoring the RLN have been developed to aid visual information during surgery; such monitoring information provides a powerful new functional dynamic during surgery. Lower rates of facial nerve paralysis, for example, have been documented with facial nerve monitoring following otoneurologic skull base surgery.\textsuperscript{15,16} Several large case series have similarly used intraoperative neural monitoring in the United States and Germany during thyroid surgery with equally positive results.\textsuperscript{17-20} Intraoperative RLN monitoring has 3 roles: to aid in accurate and expedient identification of the RLN, to aid in dissection of the RLN through difficult surgical fields, and most importantly to provide prognostic information regarding postoperative RLN function. The latter can be particularly helpful in determining the optimal time for contralateral surgery with the goal of avoiding bilateral vocal cord paralysis.\textsuperscript{1}

Methods used for intraoperative neural monitoring include intraoperative visualization of the glottis by laryngoscopy during surgery,\textsuperscript{19} laryngeal palpation during RLN stimulation,\textsuperscript{15,20} and the use of intramuscular electrodes to detect laryngeal muscle EMG activity in response to RLN stimulation.\textsuperscript{2,14,17} Our institution's preference, in both pediatric and adult surgical cases, is the Xomed NIM II monitoring system because it provides the surgeon both an intraoperative audio signal as well as quantifiable EMG data. Good correlation has been established between EMG measured on the Xomed NIM endotracheal tube and that measured by intracordal invasive hookwires.\textsuperscript{1,21} The choice of location for placement of the monitoring endotracheal tube is best guided by a standard algorithm followed by both the otolaryngology and anesthesia specialties.\textsuperscript{1} Our preference for the Xomed NIM II system is based on an extensive adult thyroid surgery monitoring experience of over 1300 nerves at risk, approximately 36% of the cases representing malignant neoplasm and 10% revision surgery. All patients were examined preoperatively and postoperatively, and the permanent paralysis rate was 0%, and the temporary paresis rate was 0.36%.\textsuperscript{1}

The present report is not the first to describe intraoperative neural stimulation of the RLN during pediatric thyroid surgery. A retrospective case study\textsuperscript{22} performed at a single institution examined 97 children undergoing various thyroid procedures. In that study, neural RLN monitoring was used in 53 cases by inserting a bipolar electrode directly through the cricothyroid membrane into the thyroarytenoid muscle. In 44 cases, the RLN was only visually identified. In these 44 visualization-only cases, there was a temporary paresis rate of 4.55% and a permanent paralysis rate of 2.27%. In the group receiving RLN visualization in combination with intraoperative monitoring, there was no permanent paralysis, and the temporary paresis rate was only 1.81%. An additional study of 11 patients undergoing surgical excision of benign or malignant thyroid disease incorporating needle electrode monitoring of both the RLN and the external branch of the superior laryngeal nerve reported transient paresis of only 1 RLN.\textsuperscript{23} The authors of both these studies conclude that neural monitoring of the RLN was both helpful and predictive of postoperative vocal fold function.

Neural monitoring has also been shown to offer advantage during patent ductus arteriosus (PDA) ligation in children and infants, another pediatric procedure that puts the RLN at risk. Studies have demonstrated the incidence of RLN injury during PDA ligation to range from 8.8% in the standard open thoracotomy approach to 2.3% when PDA ligation is performed by video-assisted thoracoscopic surgery (VATS).\textsuperscript{24} Electromyographic monitoring of the RLN via percutaneously placed needle electrodes into the cricoarytenoid membrane has been applied to a case series of 60 infants undergoing elective VATS for PDA.\textsuperscript{25} The investigators found that direct stimulation was greatly effective in localizing the RLN and facilitated dissection and clipping of the ductus arteriosus. Of the 60 subjects in the study, only 1 patient had transient hoarseness, and there was no evidence of permanent RLN injury in any patient. In our small case series we successfully used the Xomed NIM II endotracheal tube RLN monitoring system for passive and evoked intraoperative neural monitoring. Similar to our institution's experience in adults, we found the endotracheal tube–based surface electrode system to be...
simple, noninvasive, and easy to use. The principal disadvantage is that current limitations in electrode endotracheal tube size (the smallest commercially available tube has an 8.8-mm OD) restrict its use to older children and adolescents 13 years of age or older. The investigatory prototype tube used in the youngest patient in this series had an OD of 7.8 mm and would potentially allow this technique to be used on patients as young as 10 years. Care should be taken not to use inappropriately sized endotracheal tubes in younger children because the tube itself might cause vocal fold trauma.

Alternative options in younger, smaller children include an electrode pad designed for extraluminal postcricoid placement (Neurovision Medical, Ventura, California) (Figure 4) or surface electrodes that can be applied to standard, smaller-diameter, cuffed endotracheal tubes (Neurovision Medical) (Figure 5). In the latter case, the surface electrode pad must be carefully trimmed to avoid overlap, which can cause electrode malfunction. The postcricoid electrode pad requires intraoperative laryngoscopy for placement. Neither of these 2 techniques has an established track record for intraoperative monitoring accuracy.

In conclusion, RLN monitoring deserves serious consideration in the pediatric population. The commercially available endotracheal tube with an incorporated surface electrode array used in this series appears to be the most practical and noninvasive means of achieving such monitoring. The benefits of RLN monitoring include more expedient and accurate identification of the RLN, enhanced surgical RLN dissection, and immediate intraoperative assessment of RLN integrity. Such monitoring also allows the surgeon to document that the RLN was indeed preserved by a timed, recorded nerve signal; this objective proof of intraoperative nerve identification and function could be useful in a medicolegal context. The greatest limitation to the incorporation of endotracheal tube EMG monitoring in pediatric surgical practice is the larger size of the endotracheal tubes: the smallest commercially available tube is appropriate for use only for patients 13 years or older. A smaller prototype tube under investigation may expand the use of this technique to younger patients. Alternative, less well-established monitoring options exist for younger children, but the utility and cost-effectiveness of such techniques must be evaluated by future studies.

Submitted for Publication: February 12, 2007; final revision received September 5, 2007; accepted September 21, 2007.

Correspondence: W. Michael J. Cunningham, MD, Massachusetts Eye and Ear Infirmary, 243 Charles St, Boston, MA 02114 (Michael_Cunningham@meei.harvard.edu).

Author Contributions: Dr White had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: White, Randolph, and Cunningham. Acquisition of data: White. Analysis and interpretation of data: White, Randolph, Hartnick, and Cunningham. Drafting of the manuscript: White, Randolph, and Cunningham. Critical revision of the manuscript for important intellectual content: White, Randolph, and Cunningham. Statistical analysis: White. Administrative, technical, and material support: White. Study supervision: White, Randolph, Hartnick, and Cunningham.

Financial Disclosure: None reported.

Previous Presentation: This study was presented as a poster at the Annual Meeting of the American Society of Pediatric Otolaryngology; May 28-30, 2005; Las Vegas, Nevada.

REFERENCES

15. Leonetti JP, Brackmann DE, Prass RL. Improved preservation of facial nerve func-

Figure 5. Neurovision Medical (Ventura, California) electromyographic electrode pad adaptable to the outside surface of standard endotracheal tubes.


---

**Announcement**

**Call for Photographs**

*Archives of Otolaryngology–Head & Neck Surgery* is always seeking interesting cover photographs. Since many of our readers are excellent amateur photographers, we would appreciate submissions of choice photographs to us. Please e-mail them as an attachment, in .jpg or .tif format, to archoto@jama-archives.org or, if necessary, mail them to *Archives of Otolaryngology–Head & Neck Surgery*, 183 Tuckahoe Farm Ln, Charlottesville, VA 22901. Contact Susan Levine, Editorial Manager, with any questions at (434) 960-9202.