Intraoperative Laryngeal Nerve Monitoring During Thyroidectomy

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Objective: To determine whether nerve integrity monitoring during thyroidectomy predicts recurrent laryngeal nerve (RLN) function after surgery.

Design: Prospective cohort outcomes study

Patients: The study included 210 consecutive patients with thyroid abnormalities who underwent thyroidectomy.

Methods: All patients were intraoperatively monitored with a nerve integrity monitoring system (Xomed NIM II; Medtronic Inc, Fridley, Minnesota), and their vocal cord function was assessed with fiberoptic laryngoscopy before and after surgery. Normal and impaired vocal cord function were compared using an independent t test with respect to postoperative vocal cord mobility, length of the RLN dissection, and the minimum stimulus needed to generate a response at the completion of surgery.

Results: There was a statistically significant difference between the stimulus in milliamperes required to stimulate normal vs abnormal functioning nerves at the completion of the procedure at the cricoarytenoid joint (P = .02) and at the distal end of the RLN dissection (P < .01). A greater length of dissected nerve was associated with normal vocal cord function; however, it was not statistically significant (P = .07).

Conclusion: These data suggest that an RLN that responds at lower-intensity stimulation (≤0.5 mA) at the end of thyroid surgery is associated with normal vocal cord mobility.


Recurrent laryngeal nerve (RLN) paralysis is one of the most concerning complications after thyroid surgery. Symptoms range from dysphonia to severe airway compromise. Reported rates of RLN injury range from 1% to 8%, with cases involving reexploration, radiation exposure, and large goiters resulting in a higher incidence of injury. Injury can occur as a result of stretch, pressure, crush, electrocautery, suction trauma, and ischemia, all of which can be difficult to assess during surgery. Two studies involving more than 1000 and 27,000 nerves at risk revealed that visual identification of the nerve decreased the rates of permanent RLN palsies when compared with cases with no visual identification. There is controversy in the literature regarding whether or not intraoperative nerve monitoring decreases the risk of injury or simply increases cost. Factors other than nerve monitoring, such as surgeon experience, have been cited as more influential risk factors for RLN palsy. There are several methods of RLN monitoring, including palpation of the posterior cricoarytenoid muscle twitch, needle electrodes placed in the vocalis or thyroarytenoid muscle, postcricoid electrodes placed in the hypopharynx, or use of an endotracheal tube with integrated and exposed wire electrodes that contact the vocal cords.

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This prospective cohort study was performed from January 1998 to January 2009. Institutional review board approval was obtained for the study, and all patients who consented to a partial or total thyroidectomy were enrolled. Two endocrine surgeons (K.T.P. and R.C.) used intraoperative RLN monitoring in 210 consecutive patients, for a total of 273 nerves at risk. Preoperative flexible laryngoscopy confirmed normal vocal cord mobility in all patients. Twelve patients were excluded owing to impaired preoperative vocal cord function, an inability to identify the RLN intraoperatively, malfunction of the machine, and necessity of intentional nerve sacrifice because of cancer.

The Xomed NIM II monitoring system was used in all cases to monitor, test, and confirm visual identification of the RLN at the completion of the case. Patients were intubated with the NIM contact endotracheal tube. Electrodes were situated at the level of the true vocal cords. Endotracheal tube position was confirmed by the surgeon, with appropriate electromyographic signaling and direct laryngoscopy. The nerve stimulator was set at 0.5 mA, and when the RLN was visually identified, it was stimulated with 0.5 mA to confirm identification and machine function. In some cases, if there was no response, 1.0 mA and then 2.0 mA stimuli were used. The number of times that the RLN was stimulated during the case was also recorded. Once the specimen was removed and hemostasis was obtained, each nerve was stimulated at the cricoarytenoid joint at 0.25 mA, and if there was no response, the stimulus was increased successively to 0.35, 0.5, 1.0, and 2.0 mA until a positive NIM response was achieved. Nerve testing was repeated at the most distal location of RLN dissection from the cricoarytenoid joint, and the smallest stimulus to generate a response at the cricoarytenoid joint and distal dissection was recorded for each nerve. The length of the dissected nerve was measured and recorded. At the first postoperative appointment, 1 to 2 weeks after surgery, flexible laryngoscopy was performed in all cases.

Pathology reports and information regarding patients' preoperative and postoperative vocal cord mobility were reviewed and documented. Permanent vocal cord paralysis was defined as impaired mobility at 3 to 4 months after surgery. Statistical analysis was performed using a t test for continuous data. Statistical significance was set at $P \leq .05$.

### RESULTS

The final pathology report documented 92 multinodular goiters, 63 benign adenomas, 40 papillary carcinomas, 5 follicular cell carcinomas, 8 cases of Hashimoto thyroiditis, and 2 cases of Graves disease. Unilateral vocal cord paralysis or paresis was confirmed in 10 patients (4.7%) at 1 week after surgery. Five of 10 patients did not return beyond their 1 week postoperative appointment. Vocal cord dysfunction resolved in 4 of the 5 patients who did return, and 1 patient's dysfunction persisted at the 6-month follow-up visit. Analysis of the 10 cases of abnormal vocal cord mobility after surgery revealed 1 patient with an adenoma, 2 patients with papillary carcinoma, and 7 patients with multinodular goiter.

The length of the dissected RLN was analyzed with respect to normal and abnormal nerve function; 273 RLNs were analyzed. The nerves functioning normally after surgery ($n=263$) were noted to have a mean dissection length of 21.48 mm, while the nerves functioning abnormally were dissected at an average length of 15.00 mm ($P=0.07$).

Stimulation of the RLN at the cricoarytenoid joint after surgery revealed an average stimulation at 0.44 mA for normally functioning nerves ($n=248$) and at 0.62 mA for abnormally functioning nerves ($n=10$) ($P=0.02$). Stimulation at the most distal aspect of the dissection from the cricoarytenoid joint revealed an average stimulation of 0.43 mA for the normal functioning nerves and 0.97 mA for the abnormal functioning nerves ($n=178$ and $n=5$, respectively) ($P<0.01$) (Table). The incidence of permanent paresis and/or paralysis of the RLN after thyroidectomy is low; however, such a condition causes serious sequelae and is the most common reason for legal claims. Although intraoperative nerve monitoring was proposed more than 30 years ago, the prevalence of its use is low compared with facial nerve monitoring in parotid surgery. Several articles have attempted to clarify whether the nerve monitor provides any benefit over routine visual identification. Shindo and Chheda compared patients who underwent thyroid surgery with and without continuous nerve monitoring with the Xomed NIM II system ($N=1034$ nerves at risk) and found a trend toward lower rates of paralysis with the use of nerve monitoring; however, the difference was not statistically significant. Several studies found similar results with intraoperative nerve monitoring, concluding that the nerve monitor can accurately verify an intact nerve (high negative predictive values) but that it is poor at identifying a loss of nerve function (low positive predictive values). Even in the face of similar study results, conclusions vary, with some authors recommending the routine use of continuous intraoperative nerve monitoring, some advocating its use only in difficult cases, and others stating that visual identification alone is sufficient. One of the limitations of our study is that only a small number of subjects with impaired postoperative vocal cord mobility were analyzed. Similar to other studies, the rate

### Table. Intraoperative Nerve Dissection and Stimulation

<table>
<thead>
<tr>
<th>Nerve Function</th>
<th>No.</th>
<th>Mean</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length dissected, mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>263</td>
<td>21.4</td>
<td>.07</td>
</tr>
<tr>
<td>Abnormal</td>
<td>10</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>Proximal stimulation, mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>248</td>
<td>0.44</td>
<td>.02</td>
</tr>
<tr>
<td>Abnormal</td>
<td>10</td>
<td>0.82</td>
<td></td>
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<tr>
<td>Distal stimulation, mA</td>
<td></td>
<td></td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Normal</td>
<td>178</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>Abnormal</td>
<td>5</td>
<td>0.97</td>
<td></td>
</tr>
</tbody>
</table>
of vocal cord paralysis was low; therefore, it is difficult to obtain data regarding damaged nerves. Brennan et al found conclusions that were similar to those of our study with respect to the prognostic implications. Analyzing 96 RLNs at risk, they observed that all postoperative normal functioning nerves were stimulated at 0.4 mA or less. The 1 nerve that displayed temporary paralysis was stimulated at 0.5 mA. Another study that tested 37 RLNs intraoperatively with the Xomed NIM system revealed that normally functioning nerves were stimulated at a mean of 0.3 mA, but data concerning paralyzed nerves were lacking.8

Postoperative laryngeal examinations are necessary to determine mobility of the RLN. Normal vocal quality does not ensure symmetrical vocal cord movement. The importance of intraoperative visual identification and adequate dissection of the nerve was also suggested by our study. Although only a statistical trend was observed, the normally functioning nerves were dissected to a greater length than the nerves that presented with paralysis or paresis 1 week after surgery.

Our data suggest that there is a statistically significant difference between the milliamperes that are required to stimulate vocal folds with normal and abnormal mobility. We also found that there was a large difference when the nerve was tested at the most distal aspect of the dissected RLN. It is difficult to make diagnostic conclusions unless large numbers of abnormal nerves can be examined, yet these data suggest that the NIM II may provide information that can predict postoperative vocal cord function. Similar future studies with greater power may corroborate these findings and determine whether nerve testing can predict temporary vs permanent vocal cord dysfunction.

One of the inherent limitations of using the laryngeal nerve monitor is that, as with any other technology, there is a learning curve. To use it effectively, the surgeon must ensure that the endotracheal tube is positioned accurately, that the electrodes are in proper position, and that the device is set at the appropriate settings. The monitor serves as a tool to confirm that a structure is the RLN. We did not find that use of the NIM II helped to definitively locate a RLN that could not be visualized. We noted many instances when the RLN was not stimulated because there was a thin layer of fascia or minimal blood covering the nerve, despite clear visual confirmation that the structure was the RLN, and some false-positives when the stimulus was set at 1.0 mA or higher.

No nerve monitoring system can substitute for careful dissection and visual nerve identification during thyroid surgery. Recurrent laryngeal nerve monitoring technology continues to improve, and while some surgeons find continuous monitoring systems useful, the low positive predictive value limits its clinical usefulness with respect to identification of a nerve that is not visualized.

In conclusion, our findings suggest that the Xomed NIM II system may offer valuable prognostic information concerning postoperative vocal cord mobility. However, given the low incidence of impaired nerves after surgery, it is difficult to make clear guidelines. A large multi-institutional prospective study may help to definitively answer questions regarding the usefulness of intraoperative laryngeal nerve monitoring. Surgeons must keep in mind that, although technology continues to advance, there is no substitution for positive identification and careful dissection of the RLN.

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Study concept and design: Donnellan, Pitman, Cannon, and Simmons. Acquisition of data: Donnellan, Pitman, Cannon, and Simmons. Analysis and interpretation of data: Donnellan, Pitman, Cannon, and Replogle. Drafting of the manuscript: Donnellan, Pitman, and Simmons. Critical revision of the manuscript for important intellectual content: Donnellan, Pitman, Cannon, Replogle, and Simmons. Statistical analysis: Replogle. Administrative, technical, and material support: Simmons. Study supervision: Donnellan, Pitman, and Cannon.

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REFERENCES