Intraoperative electromyographic monitoring of the recurrent laryngeal nerve in reoperative thyroid and parathyroid surgery

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Background. *Injury to the recurrent laryngeal nerve (RLN) is a rare complication of initial thyroid and parathyroid surgery, but the prevalence is much higher in the reoperative setting. The use of continuous, intraoperative electromyographic monitoring of the RLN has been suggested to improve the safety of cervical explorations.*
Methods. *Outcomes of a group of reoperative thyroid and parathyroid cases that used EMG monitoring with endoscopically applied hook-wire electrodes were compared with a group of cervical reoperations without monitoring. Office laryngoscopy (indirect or fiberoptic) was used to evaluate and follow suspected RLN complications.*
Results. *Electromyography was used in 52 cervical reexploration procedures. Patients averaged 1.8 previous explorations (range, 1-7 explorations) and underwent procedures for parathyroid (31%) and/or thyroid (77%) disease (overall, 72% malignant). The nonmonitored group had 59 patients with similar characteristics. Only 1 permanent nerve complication in each group was unintended (electromyography, 1.9%; non-electromyography, 1.7%). Seven false-negative and 2 false-positive electromyographic findings occurred. No complications resulted from placement of the electromyography electrodes.*
Conclusions. *Intraoperative electromyographic monitoring of the RLN in reoperative neck surgery can be performed safely but did not decrease RLN complications in this study. Experience and routine nerve exposure remain crucial to the minimization of RLN complications. (Surgery 2004;136:1107-15.)*

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INJURY TO THE RECURRENT LARYNGEAL NERVE (RLN) is a rare but potentially debilitating complication of thyroid and parathyroid surgery. Permanent paralysis rates of zero to <2% are commonly reported for first time cervical explorations in high-volume endocrine surgery centers.[1-5] The paralysis rate in the reoperative setting is typically higher, approximately 5%, with a range from 2% to 12%.[6-10] Complications are more common in the reoperative setting because of extensive scarring, distortion of typical dissection planes and anatomic relationships, and proximity of the disease that necessitates reoperation to the RLN. Injury to the RLN can result in a weak, breathy voice, dysphagia, aspiration, and if bilateral, respiratory distress and loss of airway patency.

A thorough knowledge of anatomy and meticulous identification of the RLN along its course in the neck generally has been considered the best method for the protection of the RLN.[4] Intraoperative physiologic monitoring of the RLN has been suggested as an adjunct to reduce the incidence of injury to the RLN.[11-19] The present study examines the use of continuous, intraoperative electromyography of the RLN during cervical reexplorations for various thyroid and parathyroid disorders and compares outcomes to a similar

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group of cervical reexplorations with no electromyographic monitoring.

PATIENTS AND METHODS

Fifty-two patients who underwent reoperative cervical exploration procedures for thyroid or parathyroid disease with electromyographic monitoring of the RLN at the Mayo Clinic between October 1998 and January 2003 were reviewed. Most of these cases (42/52 patients; 81%) were consecutive reoperations after 2000, when electromyographic monitoring for repeat exploration procedures became the common practice for one of the authors (G.B.T.). The medical records, operative notes, and pathology reports were analyzed and compared with a group of 59 consecutive patients who underwent cervical reexploration procedures for thyroid and parathyroid disease between 1998 and 2000 without electromyographic monitoring of the RLN.

Monitoring technique. After the induction of general endotracheal anesthesia, a Dedo laryngoscope was used for endoscopic placement of 2 hook-wire electrodes into the vocalis muscle of each side that would be undergoing exploration procedures. The electrodes were connected to a freestanding electromyography machine for continuous monitoring of background muscle activity and evoked potentials with a handheld nerve stimulator. An electromyography technician was present throughout the procedure to monitor activity changes and to confirm evoked potentials. Neurotonic discharges were considered indicative of stress or potential injury to the RLN. Absolute electromyographic indicators of nerve damage were determined by complete loss of background activity and the inability to demonstrate evoked potentials by direct stimulation of the ipsilateral vagus nerve. All RLNs that were at risk in both groups were identified and protected along the course in the neck. In 3 cases, the nerve was infiltrated and encased by tumor and resected.

Risk to the RLN was stratified on the basis of physical proximity of disease. The disease was classified as "unrelated" if it did not adhere directly to the nerve on that side; "adherent" if the disease was in intimate apposition to the nerve, but careful dissection rendered the nerve intact; and "involved" in cases in which the RLN had to be sacrificed to adequately resect tumor.

Preoperative vocal cord checks were performed routinely with office laryngoscopy (indirect or fiberoptic). RLNs that demonstrated paralysis before the operation (n = 8 cases) were excluded from statistical analysis, which left 72 RLNs in the electromyography group and 79 RLNs in the unmonitored (control) group at risk. Postoperative vocal cord checks were performed selectively to confirm cases of suspected injury, based on clinical impression or loss of electromyographic activity during the procedure. Sixteen patients (30.8%) in the electromyography group and 17 patients (28.8%) in the control group had a postoperative cord check. A RLN complication was identified on the basis of the presence of symptoms and vocal cord dysmotility on laryngoscopy. A nerve paresis was considered a temporary neuropraxia if the patient experienced symptomatic resolution and the vocal cords regained mobility.

Statistical analysis. Continuous variables were compared using 2-sample *t* tests or Wilcoxon rank sum tests, when appropriate. Categoric nominal variables were compared with the use of chi-square tests or Fisher's exact tests. Analyses were based on a per-patient or per-nerve basis. For these latter comparisons, generalized estimating equations[20] were used in a generalized linear models framework[21] to account properly for the within-patient correlation. All statistical tests were 2-sided and probability values of <.05 were considered significant.

RESULTS

Fifty-two patients underwent reoperative cervical exploratory procedures with electromyographic monitoring and were compared with 59 patients who underwent reexploratory procedures without monitoring. Age, the ratio of female to male patients, the number of previous cervical exploratory procedures, the procedures that were performed, and the pathologic diagnoses did not differ significantly between the 2 groups (Table I). The average time in the operating room was 3 hours for the electromyography group and 2.5 hours for the unmonitored group ($P = .01$. More patients in the electromyography group had preoperative hoarseness, dysphagia, or a symptomatic neck mass (9 vs 3 patients; $P = .04$).

Seventy-two patients with RLNs were at risk in the electromyography-monitored group, and 79 patients with RLNs were at risk in the unmonitored group. RLN risk was stratified on the basis of physical proximity and the relationship of the disease to the nerve and was not significantly different between the 2 groups (Table I). Most patients with RLNs (74%) had disease that was adherent or in close approximation; careful dissection left the nerve intact. Three RLNs (1 electromyography and 2 unmonitored) were sacrificed intentionally because of malignant invasion.

Table I. Characteristics of patients who underwent reoperative cervical exploration procedures with continuous, intraoperative electromyographic monitoring of the RLN vs patients without electromyography monitoring

Characteristic	*Electromyography (n=52)*	*No electromyography (n=59)*	P *value**
Age (y)†	51.1 (13-76)	50.4 (5-85)	.62
Female (n)	33 (63.5%)	37 (62.7%)	.93
Preoperative symptoms (n)‡	9 (17.3%)	3 (5.1%)	.04
Previous cervical explorations (n)†	1.8 (1-7)	1.6 (1-6)	.45
Operative time (hr)†	3.0 (1.0-8.75)	2.5 (0.5-7.75)	.01
Procedures (n)§			
Thyroid	41 (78.8%)	37 (62.7%)	.57
Thyroid bed	29 (55.8%)	23 (39.0%)	
Completion thyroidectomy	6 (11.5%)	6 (10.2%)	
Thyroid lobectomy	2 (3.8%)	5 (8.5%)	
Total thyroidectomy	2 (3.8%)	3 (5.1%)	
Lateral lymph node dissection	14 (26.9%)	18 (30.5%)	.68
Parathyroid gland	15 (28.8%)	20 (33.9%)	.57
Extrathyroidal structures‖	4 (7.7%)	7 (11.95)	.46
Pathologic condition (n)§			
Thyroid carcinoma	38 (73.1%)	35 (59.3%)	.13
Benign thyroid disease	5 (9.6%)	3 (5.1%)	.47
Parathyroid adenoma	15 (28.8%)	22 (37.3%)	.35
Parathyroid carcinoma	1 (1.9%)	2 (3.4%)	NA
RLN (n)	72	79	
Disease unrelated to RLN	17 (23.6%)	19 (24.1%)	.99
Disease adherent to RLN	54 (75.0%)	58 (73.4%)	
Disease involved RLN	1 (1.4%)	2 (2.5%)	

NA, Not available.
**P* <.05 was considered to be significant.
†Data are given as the mean (range).
‡Symptoms include hoarseness, dysphagia, and/or a symptomatic neck mass.
§Some patients had more than 1 procedure and/or disease.
‖Extrathyroidial structures include strap muscles, tracheal rings, and/or esophagus.

The remaining RLNs were uninvolved by the disease that necessitated reexploration but remained at risk because of scaring and anatomic distortion in the region. Ten patients in the study (3 patients in the electromyography group and 7 patients in the non-electromyography group) underwent lateral cervical lymph node dissection without concomitant thyroid bed reexploration. One patient in each group had malignant lymph nodes that were densely adherent to the vagus nerve and was stratified in the adherent group; the remaining cases were classified as unrelated disease. Of note, the patient in the unmonitored group with adherent nodes to the vagus experienced a postoperative temporary neuropraxia of the ipsilateral vocal cord, despite no central neck dissection.

As shown in Table II, 10 of 52 patients (19%) in the electromyography-monitored group experienced a temporary or permanent RLN complication. This rate was not statistically different from the unmonitored group, in which 10 of 59 patients (16.9%) experienced a complication ($P > .10$). One patient in each group had evidence of bilateral RLN injury; therefore, 11 of 72 patients (15.3%) with electromyographic monitoring of RLNs and 11 of 79 patients (13.9%) with unmonitored RLNs were injured ($P > .10$). Of the paralyzed RLNs, 1 RLN in the electromyography group and 2 RLNs in the unmonitored group were sacrificed intentionally because of nerve involvement by invasive carcinoma (papillary thyroid cancer in the electromyography monitored patient and parathyroid cancer in both unmonitored patients). Among complications with an intact RLN after dissection in the electromyography group, 8 cases (15.4%) and 9 RLNs (12.5%) were temporary neuropraxis that subsequently regained function. One unintentional injury (1.9% of cases, 1.4% of RLNs) in the electromyography group was permanent. These results were similar to the unmonitored group, in which 7 patients (8 RLNs) experienced a temporary neuropraxia; 1 injury was unintentional and permanent (1.7% of cases and 1.3% of RLNs).

Table II. Complications of the RLN in electromyography-monitored and nonmonitored groups by patient and by nerves at risk

Complication	*Electromyography*	*No electromyography*
Patients (n)	52	59
Dysfunction (n)	10 (19.2%)	10 (16.9%)
Temporary	8 (15.4%)	7 (11.9%)
Permanent, overall	2 (3.8%)	3 (5.1%)
Permanent, unintentional	1 (1.9%)	1 (1.7%)
RLNs (n)	72	79
Dysfunction (n)	11 (15.3%)	11 (13.9%)
Temporary	9 (12.5%)	8 (10.1%)
Permanent, overall	2 (2.8%)	3 (3.8%)
Permanent, unintentional	1 (1.4%)	1 (1.3%)

All were $P > .10$.

Several differences were noted among the 20 of 111 cases (18%) in which temporary or permanent RLN complications occurred (Table III). A higher proportion of patients with ≥2 previous exploratory procedures ($P = .004$) or preoperative symptoms (hoarseness, dysphagia, or a symptomatic neck mass) had a nerve complication ($P = .04$), and the operative time was longer in cases with a complication (mean, 245 vs 147 minutes; $P < .001$). Patients with a diagnosis of carcinoma were 5 times more likely to suffer a nerve complication ($P = .009$), which includes all 3 patients in the study with parathyroid carcinoma (2 after intentional sacrifice). Six of 11 patients (54.6%) whose condition required resection of locally invaded structures (such as strap muscles, tracheal rings, or esophagus) had nerve dysfunction, compared with 14 of 100 patients (14.0%) without extrathyroidal invasion ($P = .004$).

Table IV shows the electromyographic findings for all 10 patients who experienced a postoperative RLN complication. Neurotonic discharges were noted in 33 of 72 electromyography-monitored RLNs (45.8%) during the course of dissection, and 8 of these nerves (24.2%) exhibited temporary or permanent dysfunction after the operation. Six of 72 nerves (8.3%) lost all background muscle electromyographic activity and did not elicit an evoked potential at the end of dissection. One of these nerves had been intentionally sacrificed during the procedure, although 3 of these nerves were intact but demonstrated a postoperative temporary neuropraxia. In the other 2 RLNs, loss of activity was likely due to a dislodged electrode because these patients were asymptomatic with normal vocal cord mobility on postoperative laryngeal examination. Table IV shows 4 RLNs that demonstrated postoperative nerve dysfunction (1 permanent and 3 temporary) without any electromyographic evidence of injury (no neurotonic discharges, unchanged baseline activity, and intact evoked potentials). Sensitivity, specificity, and positive and negative predictive values are reported in Table V.

DISCUSSION

Reoperative thyroid and parathyroid procedures have a higher rate of complications because of scarring and loss of normal tissue planes. Additionally, the disease that necessitates reexploration procedures often is associated intimately with the RLN, especially in cases of thyroid or parathyroid carcinoma that is either recurrent in the thyroid bed or metastatic to paratracheal lymph nodes. Operating on persistent or recurrent hyperparathyroidism can also threaten the RLN when the offending parathyroid gland is located in the tracheoesophageal groove of a previously dissected field. Finally, operating on metastatic disease in lateral cervical lymph nodes can affect RLN function because of an association with the vagus nerve or from bulky nodes that extend medially when the ipsilateral thyroid lobe has been resected previously.

All of the cases in the present study were reoperative explorations, of which 72% had carcinoma and 76% had disease that was adherent to the RLN. The overall permanent nerve dysfunction rate by RLN (5/151; 3.3%) or by patient (5/111; 4.5%) that is reported here is consistent with reports of complication rates in reoperative cervical exploration procedures from high-volume endocrine surgery centers.[6-10] Excluding the 3 RLNs that were sacrificed, the rate of unintentional permanent paralysis was 1.3% for nerves at risk and 1.8% for patients at risk. The overall prevalence of temporary neuropraxia was 11.3% (17/151 RLNs). Factors that were associated with nerve complications included ≥2 previous cervical exploration procedures, preoperative dysphagia, hoarseness, or a symptomatic neck mass, a diagnosis of carcinoma (especially parathyroid carcinoma), longer operative times, adherence of disease to the RLN, and excision of extrathyroidal structures (such as strap muscles, tracheal rings, or esophagus).

Patients in both groups were selected to undergo postoperative laryngoscopy based on symptoms or clinical impression; therefore, the prevalence of RLN complications that are reported here could be underestimated in the rare event of

Table III. Characteristics of 20 of 111 reoperative cervical exploration procedures with postoperative temporary or permanent RLN dysfunction

Variable (n/N)	*Dysfunction*	P *value*	*Odds ratio (95% CI)*
Previous exploratory procedure			
Two or more	13/41 (31.7%)		
One	7/70 (10.0%)	.004	4.18 (1.51-11.60)
Preoperative symptoms			
Yes	5/12 (41.7%)		
No	15/99 (15.2%)	.04	4.00 (1.12-14.28)
Carcinoma			
Yes	18/72 (25.0%)		
No	2/39 (5.1%)	.009	6.17 (1.35-28.18)
Extrathyroidal invasion			
Yes	6/11 (54.6%)		
No	14/100 (14.0%)	.001	7.37 (1.98-27.44)
Disease proximity to RLN			
Adherent, resectable	17/81 (21.0%)		
Distant	1/28 (3.6%)	.04	7.17 (0.91-56.63)
Electromyographic monitoring			
Yes	10/52 (19.2%)		
No	10/59 (16.9%)	.76	1.17 (0.44-3.07)

$P < .05$ was considered to be significant.

an asymptomatic nerve paresis.[1] Two large, prospective studies recently examined the incidence of asymptomatic RLN dysfunction that was discovered with routine postoperative laryngoscopy. Lo et al[22] discovered 3 cases of asymptomatic dysfunction of 787 RLNs (0.4%) that were examined; Steurer et al[23] discovered 11 cases of 1080 RLNs (1.0%). Undetected RLN complications are unlikely to meaningfully affect the results presented here.

Intraoperative monitoring of RLN function has been proposed as an adjunct for identification, dissection, and detection of injury to the RLN.[11-19] Several methods have been described to monitor the RLN during neck exploration procedures, many of which involve electromyographic monitoring of laryngeal muscles that are innervated by the RLN. The use of electromyography requires direct laryngeal muscle contact by an electrode to allow continuous monitoring of spontaneous baseline muscle activity and evaluation of evoked potentials with the use of a handheld nerve stimulator. Electromyographic data are interpreted either by a trained technician in the operating room or by the surgeon when electromyographic activity is converted to an acoustic signal. One potential advantage of electromyographic monitoring is the dynamic, continuous physiologic feedback of nerve function and stress on the nerve during dissection, which theoretically could reduce the risk of injury. Additionally, the loss of baseline electromyographic activity can alert the surgeon to possible nerve injury, which would prompt an investigation for potentially treatable injuries (such as a ligature or clip that could be removed). Discovery of a transected nerve could lead to primary repair in hopes of reducing long-term muscular atrophy.

Table IV. Intraoperative electromyographic findings in the 10 patients with a RLN complication

	*Intraoperative electromyographic finding**		
Patient	*Neurotonic discharge*	*Muscle potential*	*Postoperative complication*
1†	Present	Lost	Permanent paralysis
2	Present	Lost	Temporary paresis
3	Present	Lost	Temporary paresis
4	Present	Lost	Temporary paresis
5	Present	Intact	Temporary paresis
6‡	Present	Intact	Temporary paresis
7	Present	Intact	Temporary paresis
8	Absent	Intact	Temporary paresis
9	Absent	Intact	Temporary paresis
10	Absent	Intact	Permanent paralysis

*Neurotonic discharges were considered present if documented at any time during the procedure. Muscle potentials include both baseline electromyography activity and evoked potentials by stimulation of the RLN and ipsilateral vagus nerve at the end of the dissection.
†Patient 1 had intentional sacrifice of the RLN because of carcinoma invasion.
‡Patient 6 had temporary paresis of bilateral RLNs, both the exhibition of neurotonic discharges during the case and intact baseline and evoked potentials after dissection.

Table V. Sensitivity, specificity, and positive and negative predictive values for postoperative RLN dysfunction (permanent or temporary) with intraoperative electromyographic findings

Electromyographic finding	*Sensitivity (%)*	*Specificity (%)*	*Positive predictive value (%)*	*Negative predictive value (%)*
Neurotonic discharges	72.7	59.0	24.2	92.3
Loss of all activity*	36.4	96.7	66.7	89.3

*Includes loss of background vocalis muscle activity and evoked potentials.

Different techniques for electromyography electrode placement either within or in contact with laryngeal muscles have been described. Electrode wires can be inserted through the cricothyroid ligament from the operative field,[11] endoscopically applied to muscle surface[12] or within muscle with hook-wires (as in our study). Alternatively, electrodes can be attached to the endotracheal tube, either manually to a typical endotracheal tube[13,14] or to a commercially available endotracheal tube that is equipped with an indwelling electrode.[15,16] Complications have been reported (such as misplacement or subsequent dislodgment of electromyography electrodes during the procedure and RLN palsy that resulted from excessive intraoperative nerve stimulation).[14] Finally, the use of electromyographic monitoring adds expense and time to the procedure, depending on which equipment is used and who interprets the electromyographic activity. In our study, the additional professionals, equipment, and time of electromyographic monitoring added approximately 25% to the charges of the average nonmonitored case.

Intraoperative RLN monitoring techniques without electromyography have been reported. One method involves manual palpation of the posterior cricoarytenoid muscle after stimulation of the RLN.[17-18] Alternatively, visualization of stimulated vocal cord mobility can be accomplished with fiberoptic video laryngoscopy through a laryngeal mask airway.[19] The advantages of the latter technique are the use of readily available equipment and the ease of monitoring by the surgeon; however, complications of airway compromise from laryngeal edema and pneumothorax have been reported.[19]

Although the safety and feasibility of nerve monitoring is well established, its usefulness in reducing RLN injury has little support in the literature. No prospective randomized studies have been published that demonstrate a reduction of RLN injury with neuromonitoring. Thomusch et al[11] reported a statistically significant difference in permanent RLN injury rates in patients who underwent primary exploration procedures for benign goiter with electromyographic monitoring compared with patients without monitoring (0.4% vs 0.8% of RLNs, respectively). Limitations of the study included a lack of randomization; a large number of participating surgeons and centers (45 hospitals) with a wide variability of study participation and experience in thyroid surgery; few cases who underwent electromyographic monitoring (19% of eligible cases); exclusion of 42% of eligible study participants because of incomplete intraoperative identification of the RLN or carcinoma discovered in the final pathology specimen; and 5% of documented RLN injuries that were excluded because of lack of follow-up examination.

In the present study of reoperative patients at high risk for RLN injury, there was no significant difference in injury prevalence between the electromyography-monitored and unmonitored groups. The study is limited by its retrospective, nonrandomized design. There were some statistical differences that were noted between the 2 groups. More patients with preoperative symptoms were in the electromyography-monitored group (9 vs 3 patients; $P = .04$), and cases that used electromyography had significantly longer operative times (3.0 vs 2.5 hours; $P = .01$). Most characteristics, however, which include demographics, previous cervical exploration procedures, type of procedure or disease, and the physical relationship of that disease to the RLN, were similar among the 2 groups. Additionally, some of the time difference in the operating room can be attributed to the application of electrodes, the setup of the electromyography monitoring equipment, and the use of the handheld stimulator during the procedure. Although patients were selected initially to undergo monitoring by surgeon preference, most electromyography cases in the study (81%) were consecutive reoperative exploration procedures after 2000, when the use of the technique temporarily became the standard approach for one of the authors.

The use of intraoperative electromyographic findings to predict postoperative RLN dysfunction is problematic. Neurotonic discharges merely represent stress to the RLN and "potential" injury. In our study, discharges were recorded in 8 of 11 RLNs that exhibited postoperative dysfunction but also were noted in 25 of 61 RLNs (41.0%) without evidence of postoperative dysfunction, which yielded a positive predictive value of only 24%. Loss of all background electromyographic activity and stimulated potentials was more predictive (4/6 RLNs that demonstrated postoperative dysfunction) but was not very sensitive (36%). Finally, in the one instance of a permanent paralysis with an intact RLN after dissection, no neurotonic discharges were recorded; no changes in normal baseline electromyography activity was observed, and an intact RLN evoked potential at the end of dissection, which was a clear failure of intraoperative electromyography to predict postoperative nerve dysfunction. A possible explanation for the failure is that the case involved a delayed ischemic injury.

One report evaluated the use of intraoperative RLN stimulation as a test for the prediction of postoperative injury and determined its sensitivity and specificity to be 75% and 92%, respectively, with a negative predictive value of 99% but a positive predictive value of only 33%.[17] Although no study has established sensitivity and specificity for continuous electromyography monitoring as a predictor of postoperative RLN function, misleading results occur because of neurotonic discharges, misinterpretation of background electromyographic activity, misplacement or dislodgement of electrodes, misidentification of the RLN, inadequate intensity of stimulation, or stimulating the RLN distal to the site of an unrecognized injury. This latter situation may be avoided by stimulating the RLN and the ipsilateral vagus nerve during and after the dissection.

Despite a lack of evidence for reducing or reliably predicting RLN injury, nerve monitoring may have potential advantages in very select situations. Monitoring an intact RLN on the side of a planned exploration procedure in a patient with a documented contralateral vocal cord paralysis may be useful. A suspected injury to the previously functioning nerve can prompt investigation of cord mobility in the operating room before complete extubation to possibly avoid a potential airway emergency if both vocal cords are paralyzed. Another potential role for electromyographic monitoring is during a planned exploration procedure in a patient with increased risk of bilateral nerve injury (disease that involves both tracheoesophageal grooves). If an injury is suspected on the initial side of exploration, consideration could be given for a staged operation after allowing the injury time to resolve. Finally, some patients will request the use of the technology after having learned of its existence from their primary care physician, the lay press, or the Internet. As our society becomes more litigious, some surgeons may resort to using this technology routinely or in select patients out of fear of legal repercussions. Studies such as ours point to the value of experience over technology in reducing injury to the RLN.

In conclusion, although intraoperative physiologic monitoring of the RLN with electromyography is technically feasible and safe, its true efficacy and role in thyroid and parathyroid procedures has yet to be defined clearly. In this review of high risk reoperative cervical exploration procedures, there was no apparent clinical benefit to electromyographic monitoring but rather a significantly increased cost. Short of a prospective, randomized trial that both establishes the true predictive ability and demonstrates clinical usefulness, electromyographic monitoring should not be considered standard-of-care in thyroid and parathyroid surgery, especially in primary exploration procedures in which, at best, only modest benefit is possible. Locating the RLN is generally not the source of injury, but rather resection of close disease places the nerve at most risk. Electromyographic monitoring will not reduce this risk but may simply alert the surgeon to a complication that will become clinically evident regardless. The most proven method to decrease RLN injury continues to be surgical experience with a thorough knowledge of anatomy and meticulous identification and protection of the nerve along its course in the neck.

REFERENCES

1. van Heerden JA, Groh MA, Grant CS. Early postoperative morbidity after surgical treatment of thyroid carcinoma. Surgery 1987;101:224-7.
2. Harness JK, Fung J, Thompson NW, Burney RE, McLeod MK. Total thyroidectomy: complications and technique. World J Surg 1986;10:781-6.
3. Clark OH, Levin K, Zeng QH, Greenspan FS, Siperstein A. Thyroid cancer: the case for total thyroidectomy. Eur J Cancer Clin Oncol 1988;24:305-13.
4. Hermann M, Alk G, Roka R, Glaser K, Freissmuth M. Laryngeal recurrent nerve injury in surgery for benign thyroid diseases: effect of nerve dissection and impact of individual surgeon in more than 27,000 nerves at risk. Ann Surg 2002;235:261-8.
5. Lo CY, Kwok KF, Yuen PW. A prospective evaluation of recurrent laryngeal nerve paralysis during thyroidectomy. Arch Surg 2000;135:204-7.
6. Beahrs OH, Vandertoll DJ. Complications of secondary thyroidectomy. Surg Gynecol Obstet 1963;117:535-9.
7. Levin KE, Clark AH, Duh QY, Demeure M, Siperstein AE, Clark OH. Reoperative thyroid surgery. Surgery 1992;111: 604-9.
8. Patow CA, Norton JA, Brennan MF. Vocal cord paralysis and reoperative parathyroidectomy. Ann Surg 1986;203:282-5.

9. Goretzki PE, Simon D, Frilling A, Witte J, Reiners C, Grussendorf M, et al. Surgical reintervention for differentiated thyroid cancer. Br J Surg 1993;80:1009-12.
10. Muller PE, Jakoby R, Heinert G, Spelsberg F. Surgery for recurrent goiter: its complications and their risk factors. Eur J Surg 2001;167:816-21.
11. Thomusch O, Sekulla C, Walls G, Machens A, Dralle H. Intraoperative neuromonitoring of surgery for benign goiter. Am J Surg 2002;183:673-8.
12. Marcus B, Edwards B, Yoo S, Byrne A, Gupta A, Kandrevas J, et al. Recurrent laryngeal nerve monitoring in thyroid and parathyroid surgery: the University of Michigan experience. Laryngoscope 2003;113:356-61.
13. Horn D, Rotzscher VM. Intraoperative electromyogram monitoring of the recurrent laryngeal nerve: experience with an intralaryngeal surface electrode. Langenbeck's Arch Surg 1999;384:392-5.
14. Hemmerling TM, Schmidt J, Bosert C, Jacobi KE, Klein P. Intraoperative monitoring of the recurrent laryngeal nerve in 151 consecutive patients undergoing thyroid surgery. Anesth Analg 2001;93:396-9.
15. Eisele DW. Intraoperative electrophysiologic monitoring of the recurrent laryngeal nerve. Laryngoscope 1996;106:443-9.
16. Brennan J, Moore EJ, Shuler KJ. Prospective analysis of the efficacy of continuous intraoperative nerve monitoring during thyroidectomy, parathyroidectomy, and parotidectomy. Otolaryngol Head Neck Surg 2001;124:537-43.
17. Otto RA, Cochran CS. Sensitivity and specificity of intraoperative recurrent laryngeal nerve stimulation in predicting postoperative nerve paralysis. Ann Otol Rhinol Laryngol 2002;111:1005-7.
18. Echeverri A, Flexon PB. Electrophysiologic nerve stimulation for identifying the recurrent laryngeal nerve in thyroid surgery: review of 70 consecutive thyroid surgeries. Am Surg 1998;64:328-33.
19. Eltzschig HK, Posner M, Moore FD. The use of readily available equipment in a simple method for intraoperative monitoring of the recurrent laryngeal nerve function during thyroid surgery: initial experience with more than 300 cases. Arch Surg 2002;137:452-7.
20. Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. Biometrika 1986;73:13-22.
21. McCullagh P, Nelder JA. Generalized linear models. New York: Chapman and Hall; 1983.
22. Lo CY, Kwok KF, Yuen PW. A prospective evaluation of recurrent laryngeal nerve paralysis during thyroidectomy. Arch Surg 2000;135:204-7.
23. Steurer M, Passler C, Denk DM, Schneider B, Niederle B, Bigenzahn W. Advantages of recurrent laryngeal nerve identification in thyroidectomy and parathyroidectomy and the importance of preoperative and postoperative laryngoscopic examination in more than 1000 nerves at risk. Laryngoscope 2002;112:124-33.

DISCUSSION

Dr Ashok R. Shaha (New York, NY). There has been a lot of talk about nerve monitoring in primary and secondary thyroid surgery. You have reported mainly the secondary procedures, and that is where the question comes as to whether we should use the nerve monitor. The issue is not in finding the nerve. The nerve monitor is good once you find the nerve to confirm what you have seen is the nerve. The problem comes in tracing the nerve near the ligament of Berry, where we find very difficult problems, whether it is primary or secondary thyroid surgery. Secondary cases are much more difficult because of the scarring. I am not convinced, whether it is a primary case or a secondary case, that the nerve monitor will help reduce the nerve injury. Yes, the nerve monitor will tell you that something went wrong or can confirm that, once you see the nerve, this is a nerve. However, I do not think the nerve monitor will help in tracing the nerve near the ligament of Berry, avoiding blood vessel injury, and controlling the bleeding. I hope this message goes around.

Dr Henning Dralle (Halle, Germany). The main problem in recurrent laryngeal nerve monitoring is that recurrent laryngeal nerve paralysis is rare. Therefore, you need a very high number of operations to compare the results of nerve monitoring with those not using this technique. Did you make a power calculation as to how many patients you need to have a significant difference?

Which muscles are stimulated by the electrodes you used? The recurrent laryngeal nerve innervates laryngeal muscles by 2 branches, the anterior branch and the posterior branch. The posterior muscle is the only one that opens the glottis. So, which muscle is stimulated by your electrodes? Perhaps by this way you may explain why you found discrepancies between the results of nerve stimulation and nerve function.

Dr Yarbrough. Regarding the first question for the power study, we agree it was a low postoperative complication rate. Assuming a 5% permanent paralysis rate, to achieve an 80% power would require >1000 patients to reflect a meaningful difference. This study was a retrospective review of our experience with monitoring.

We also stimulated the ipsilateral vagus nerve so that it will stimulate both branches.

Dr Alan P. B. Dackiw (Baltimore, Md). I agree with Dr. Shaha's comments. Certainly identification of the recurrent laryngeal nerve lower in the neck by whatever technique is not equivalent to preventing injury to the nerve at the ligament of Berry. We must also remember that anatomic integrity of the nerve is not necessarily synonymous with functional integrity and that the nerve monitor may sometimes be helpful in predicting function after the operation.

Concerning your methods, could you please comment on your ability to determine the positive and negative predictive value of the test if you have not performed postoperative laryngoscopy? Was the nerve monitor used by both groups of surgeons in the study or exclusively by one group? Even though your conclusion was that monitoring did not prevent nerve injury, in your opinion, did it facilitate identification of the recurrent laryngeal nerve in these difficult cases, perhaps when operating in dense scar tissue? Finally, did you use the nerve monitor at all on the external branch of the superior laryngeal nerve?

Dr Yarbrough. To address the issue of asymptomatic recurrent laryngeal nerve paralysis, in our experience that occurrence is quite low. There have been 2 recent prospective trials. Lo et al from the University of Hong Kong looked at 787 nerves before and after operation and found 3 asymptomatic recurrent laryngeal nerve dysfunctions, for a rate of 0.5%. Steuer et al from the Vienna Medical School looked at >1000 recurrent laryngeal nerves prospectively and found 11 asymptomatic recurrent laryngeal nerve injuries, for a rate of 1%. So we believe that, at most, we may have missed 1 patient in our study, which probably would not have affected our data.

Concerning the question of the superior laryngeal nerve, we did not monitor this nerve, and we did not check this after the operation for dysfunction unless the patient was being examined for hoarseness.

Two surgeons contributed patients to this study and used the same techniques for electrode placement and electromyographic monitoring. It was felt that nerve monitoring did not help with the initial localization of the nerve nor did it prevent injury during dissection around the ligament of Berry.

Dr Samuel K. Snyder (Temple, Tex). We are all struggling, like your institution, with whether to use intraoperative nerve monitoring. We are kind of subject to the technology and how accurate it is in identifying these nerves.

I am a little concerned that you were able to identify nerves and stimulate them but not always evoke electromyographic potentials. That can lead to an intraoperative nerve injury if you are putting too much reliance on that technology. So, I am interested in why you thought that did not work.

Second, there is newer technology that uses endotracheal tubes with implanted electrodes. Have you had any experience with that technology and been able to compare it to your study technology?

Dr Yarbrough. Stimulating RLNs may not evoke electromyographic potentials if the hook electrode becomes displaced or if it has been stimulated too many times. In patients who had normal intraoperative EMG findings but postoperative cord paresis/paralysis, ischemic injury is postulated.

As far as the endotracheal tube, I am familiar with that technique, but we did not use it. There are other techniques that are probably less expensive. Stimulating the nerve and palpating the posterior cricoarytenoid muscle contractions with your hand is one method of monitoring the nerve. There is also a group that uses endoscopy through an LMA to evaluate the nerve intraoperatively. There are other options besides what we used.

Dr Kasperbauer. Hook-wire electrodes were all placed in the vocalis muscle endoscopically. There was a question raised regarding the ability to monitor the branches of the recurrent laryngeal nerve (for example anterior and posterior branch). Only occasionally does an anterior branch exit from the recurrent laryngeal nerve early. This tends to be a relatively small branch and identification of the muscles innervated by this particular branch would be difficult. The primary branching of the recurrent laryngeal nerve into its anterior and posterior branch occurs late, typically after the cricothyroid articulation. To monitor separately for the posterior branch, one would require monitoring the posterior cricoarytenoid muscle. Placement of hook-wire electrode in the posterior cricoarytenoid muscle would be difficult to accomplish.

In terms of monitoring the external branch of the superior laryngeal nerve, this would require a separate route of electrode placement because consistently identifying the cricothyroid muscle endoscopically would be difficult. Adding increasing levels of complexity in the monitoring situation would tend to generate more errors. When you place electrodes transorally, there can be displacement with tongue motion, neck motion, and other causes. When using hook-wire electrodes, one must rely on a technician to connect the electrodes accurately so that hopefully you are monitoring a correct site. In the reoperative setting, there are many factors in the management of these patients that require experience and consistency.

Dr Gerard M. Doherty (Ann Arbor, Mich). Have you had any experience with the other technologies for monitoring the nerve to compare them?

Dr Kasperbauer. No, I have not. In our setting, we would have to make a special effort to get electromyographic-monitoring endotracheal tubes, and hook-wire electrodes were felt to be the gold standard.