ORIGINAL ARTICLE

Incidence of Vocal Cord Paralysis With and Without Recurrent Laryngeal Nerve Monitoring During Thyroidectomy

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Objective: To compare the incidence of postoperative vocal cord paresis or paralysis in a cohort of patients who underwent thyroidectomy with and without continuous recurrent laryngeal nerve (RLN) monitoring by a single senior surgeon. We hypothesize that continuous RLN monitoring reduces the rate of nerve injury during thyroidectomy

Design: Retrospective medical chart review.

Setting: Academic tertiary care medical center.

Patients: A total of 684 patients (1043 nerves at risk) who underwent thyroid surgery under general anesthesia.

Main Outcome Measure: Incidence of vocal cord paresis or paralysis in patients who underwent thyroid surgery with continuous RLN monitoring vs those undergoing surgery without continuous RLN monitoring.

Results: The incidence of unexpected unilateral vocal cord paresis based on RLNs at risk was 2.09% (n=14) in the monitored group and 2.96% (n=11) in the unmonitored group. This difference was not statistically significant. The incidence of unexpected complete unilateral vocal cord paralysis was 1.6% in each group. Two of the 5 paralyses in the unmonitored group and 7 of the 11 paralyses in the monitored group had complete resolution.

Conclusions: Monitoring of the RLN does not appear to reduce the incidence of postoperative temporary or permanent complete vocal cord paralysis. There appeared to be a slightly lower rate of postoperative paresis with RLN monitoring, but this difference was not statistically significant.

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INJURY OF THE RECURRENT LARYNGEAL nerve (RLN) is fortunately no longer a very common complication of thyroid surgery. Nevertheless, it can be quite troublesome for patients when it does occur. Many techniques have been described to reduce the risk of nerve injury. Intraoperative identification of the nerve has been shown to decrease the risk of postoperative nerve dysfunction.[1,2] Various methods of nerve monitoring have been described, including direct visualization of the vocal cords during dissection; intermittent monitoring techniques such as palpation of the cricothyroid after stimulation of the nerve with a disposable stimulator; and continuous monitoring methods such as (1) intramuscular electromyographic (EMG) electrodes placed in the thyroarytenoid muscle, (2) postcricoid surface electrodes, and (3) surface electrodes placed between the vocal cords.[2-6]

Among the advantages of RLN monitoring are that neurapraxic injury from extended stretch may be reduced by early warning signals and that the nerve position can be confirmed by direct stimulation to differentiate it from surrounding vasculature or fibrous attachment.[5-7] Furthermore, the presence of a positive signal with stimulation at the end of the procedure has been shown to correlate with normal postoperative mobility.[3,4,8] However, the use of RLN monitoring is also associated with increased time of setup, increased cost of equipment, and the potential for false security when no warning signals are generated owing to an improperly functioning system (eg, malpositioned tube).

In recent years, it appears that RLN monitoring is probably being used with increasing frequency in the United States during thyroidectomy, partly driven by the medicolegal system. Whether its use truly reduces the risk of RLN injury has yet to be proven. Prior studies have reported on the benefit of continuous RLN monitoring. However, very few studies have ac-

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Table 1. Distribution of Procedures by Monitored and Unmonitored Recurrent Laryngeal Nerves*

Type of Operation	Total No. of Procedures	Monitored	Unmonitored
Left thyroidectomy	**152**	89	63
Right thyroidectomy	**173**	94	79
Total thyroidectomy	**211**	118	93
Total thyroidectomy and central neck dissection	**123**	107	16
Total thyroidectomy and lateral neck dissection	**25**	19	6

*All data are reported as number of procedures.

tually compared the outcome of RLN monitoring with no RLN monitoring. These studies primarily consisted of either relatively small sample sizes or multiple-surgeon compilations.[2,9] There have only been a few studies in the literature with very large sample sizes that compared the rate of postoperative RLN paralysis with and without RLN monitoring. Furthermore, variations in surgical technique of different surgeons could result in variations in rates of RLN paralysis, as shown by Hermann and colleagues,[10] who analyzed 27 000 nerve dissections by more than 11 surgeons.

Herein, we report the findings of a retrospective review of a large series of thyroidectomies performed by a single senior surgeon (M.S.) to analyze the rate of RLN paresis and paralysis with and without continuous RLN monitoring. The aim of the study was to compare the rates of impaired vocal cord mobility without variability in surgical technique. The hypothesis of the study was that continuous RLN monitoring reduces the rate of nerve injury during thyroidectomy.

METHODS

A retrospective review of all 1059 patients undergoing thyroid surgery from 1998 through 2005 was conducted. This retrospective cohort study was approved by the institutional review board. The list of all patients who underwent thyroidectomy by the senior author (M.S.) was obtained from the database of the clinical practice. Patients with preoperative impaired vocal cord function, those having surgery performed under local and intravenous sedation, and those undergoing surgery in conjunction with laryngectomy were excluded from the study. Patients with postoperative vocal cord paresis or paralysis resulting from intentional nerve sacrifice or dissection of a tumor that was encasing or severely adherent to the RLN were also excluded because the postoperative paralysis or paresis was expected in these types of cases. There was no intentional allocation of the patients to monitoring vs no monitoring The unmonitored cases were those performed when the nerve monitoring system was not available for use, primarily in the earlier years of the study. These included cases from 1998 to 2002 and those performed after 2002 where the appropriate nerve integrity monitoring system was not available for use.

A nerve integrity monitoring EMG endotracheal tube (Medtronic Xomed, Jacksonville, Fla) was used for patients undergoing continuous RLN monitoring. A member of the Department of Anesthesia intubated all patients, and the tube was positioned such that the electrodes were situated at the level of the true vocal folds oriented at 3 and 9-o'clock positions. The surgeon confirmed the endotracheal tube position by verifying appropriate EMG signals and/or direct laryngoscopy. A Prass stimulation probe (Medtronic Xomed) was used for nerve stimulation during the thyroidectomy procedure. No muscle relaxants were used after the skin flaps were elevated. The operative procedure was conducted in the same manner for all patients. In all of the patients, the RLN was identified and dissected prior to removal of the gland. The nerve was identified in the same manner in all cases and was exposed from approximately 2 to 3 cm inferior to the lower border of the cricothyroid muscle to its laryngeal entrance.[11] For those undergoing continuous nerve monitoring, the nerve was stimulated both at the time of its identification and after removal of the gland. In the unmonitored group, a standard endotracheal tube without EMG electrodes was used.

All patients underwent preoperative and postoperative laryngoscopy. The postoperative examination was performed on postoperative day 0 or 1. The incidence of "unexpected" vocal cord paresis and complete paralysis was then calculated based on the total number of nerves at risk (NAR). The data were further analyzed for differences in benign and malignant disease by calculating the overall incidence of vocal cord dysfunction (paresis or paralysis) based on the number of patients in each group.

RESULTS

Of the 1059 charts reviewed, complete data were found on 684 patients, which served as the basis for this review. The monitored group consisted of 427 patients in whom the thyroidectomy was performed with continuous nerve monitoring, and the unmonitored group consisted of 257 patients for whom nerve monitoring was not used. Total thyroidectomy with or without paratracheal node dissection or modified neck dissection was performed in 359 patients, and 325 underwent hemithyroidectomy. This resulted in 1043 NAR, 671 monitored and 372 unmonitored. Surgical procedures performed included thyroid lobectomy (including completion lobectomy), total thyroidectomy, total thyroidectomy with paratracheal lymph node dissection, and total thyroidectomy with lateral neck dissection (**Table 1**). No patients experienced a complication from the intubation of either type of tube.

Pathologic results showed both benign and malignant disease, including benign nodule, benign cyst, Hashimoto thyroiditis, Grave disease, papillary carcinoma, follicular carcinoma, Hürtle cell carcinoma, medullary cell carcinoma, anaplastic cell carcinoma, lymphoma, sarcoma, and metastatic squamous cell carcinoma. The distribution of benign vs malignant disease was relatively equal in both groups (**Figure**).

Impairment of postoperative vocal fold mobility (paresis or paralysis) was found in 25 patients from the monitored group (5.8% of patients, 3.7% of NAR) and 17 patients from the unmonitored group (6.6% of patients and 4.6% of NAR). None of the patients experienced bilateral vocal cord paralysis. One patient in the monitored group was found to have bilateral abductor paresis postoperatively, but the patient did not experience any dyspnea. The fiberoptic examination on this patient revealed bilateral arytenoid edema and erythema. The paresis in this patient was believed to be due to laryngopharyngeal reflux. The paresis improved within 24 hours of instituting aggressive antireflux therapy and had resolved by the time of subsequent examinations.

The data were further analyzed by dividing the injuries into paresis and paralysis. Fourteen monitored patients and 11 unmonitored patients were found to have vocal fold paresis postoperatively. Five of the 14 monitored patients with paresis were lost to follow-up. The vocal cord function returned to normal in the remaining 9 patients with long-term follow-up. Four of the 11 unmonitored patients were lost to follow-up. Documented resolution of the paresis occurred in 7 of the remaining unmonitored patients (**Table 2**). Unexpected complete paralysis occurred in 11 monitored patients (1.64%) and 6 unmonitored patients (1.61%) (**Table 3**). In 2 of the paralysis cases, the vocal cord did not regain full function; thus, the paralysis was considered to be permanent. In these 2 cases, the injury was due to inadvertent transection. In both cases, the injury was recognized intraoperatively, and a neurorrhaphy was performed. Vocal quality was initially breathy but improved after 6 months as the vocal cord returned to midline and regained excellent tone. Two of the monitored patients were lost to follow-up, and the paralysis resolved in 7 of the patients for whom follow-up data were available. No long-term data were available in 3 of the 6 unmonitored patients with paralysis, while 2 other unmonitored patients had complete resolution of the paralysis.

Owing to the size of the samples, a Fisher exact test was used to determine statistical significance. In comparing the overall injury occurrence rates (paresis and paralysis), we found no statistically significant difference between groups, whether the examination was performed immediately postoperatively ($P=.51$) or on subsequent examinations ($P=.32$). Similarly, in analyzing paresis and paralysis separately, when comparing monitored vs unmonitored RLNs in the immediate postoperative period, we found no statistically significant difference in the incidence of postoperative paresis ($P=.40$) or paralysis ($P>.99$). When the data were analyzed for permanent injury, no significant difference was seen for the rates of permanent paresis ($P=.72$) or paralysis ($P=.46$).

When comparing patients based on pathologic findings, we found a different relationship. In the immediate postoperative period for patients with benign disease, 6 of the 182 monitored patients and 13 of the 127 unmonitored patients experienced impairment of vocal cord mobility in the immediate postoperative period. For those patients with malignant disease processes, 18 of the 245 monitored patients and 4 of the 127 unmonitored patients had immediate vocal cord mobility impairment (**Table 4**). The lower incidence of temporary injury in the monitored group was statistically significant for the benign group ($P=.01$) and not significant in those with malignant disease ($P=.16$). On subsequent examinations, however, no significant difference emerged between the 2 groups for either benign disease ($P=.28$) or malignant disease ($P>.99$). The incidences of permanent paralysis were not statistically significant between monitored and unmonitored patients for either benign or malignant disease.

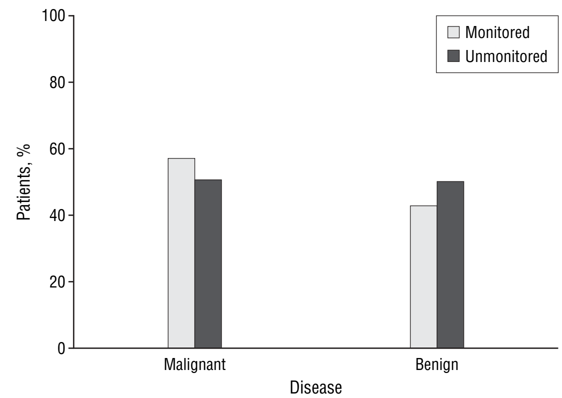

Figure. Distribution of patients by malignant vs benign disease.

Table 2. Distribution of Paresis Outcome by Monitored and Unmonitored Recurrent Laryngeal Nerves at Risk*

Outcome	Monitored (n = 671)	Unmonitored (n = 372)
Unexpected paresis, No. (%)	14 (2.09)	11 (2.96)
Lost to follow-up	5	4
Paresis resolved	9	7

*Unless otherwise indicated, all data are reported as number of nerves at risk.

Table 3. Distribution of Paralysis Outcome by Monitored and Unmonitored Recurrent Laryngeal Nerves at Risk*

Outcome	Monitored (n = 671)	Unmonitored (n = 372)
Unexpected paralysis, No. (%)	11 (1.64)	6 (1.61)
Lost to follow-up	2	3
Paralysis resolved	7	2
Permanent paralysis, %	0.3	0.3

*Unless otherwise indicated, all data are reported as number of nerves at risk.

COMMENT

Continuous nerve monitoring has become an area of keen interest in the field of thyroid surgery. A few studies have examined whether RLN monitoring actually reduces the risk of postoperative paralysis and shown conflicting results. In a retrospective review by Robertson and colleagues[9] of 165 thyroidectomy procedures performed by different surgeons, no statistically significant differences in RLN paralysis or paresis were seen between nerve monitoring and no nerve monitoring. Similarly, Beldi et al[12] reported that the incidence of RLN paralysis was not reduced by intraoperative nerve monitoring. Another report showed a significant decrease in both temporary and permanent palsy rates in an analysis of those undergoing thyroidectomy to treat benign disease.[13] However, this

Table 4. Distribution of Paresis or Paralysis Outcome by Benign and Malignant Disease and by Recurrent Laryngeal Nerve Monitoring Status*

	Benign		Malignant	
Outcome	Monitored (n = 182)	Unmonitored (n = 127)	Monitored (n = 245)	Unmonitored (n = 127)
Temporary paresis or paralysis	6	13	18	4
Permanent paresis or paralysis	3	5	6	3

*Data are reported as number of patients.

was a multi-institutional analysis of only benign disease in which patients were not randomized but selection was chosen according to the individual surgeon's preference. In a study by Hermann et al,[10] the authors concluded that nerve monitoring is useful for identifying the RLN. The limitation of the study was that the results were based on analysis of more than 11 different surgeons. Dralle and colleagues[2] analyzed the risk factors for postoperative RLN paralysis in 16 448 thyroidectomies performed at 63 different hospitals. They also concluded that when the RLN is identified during the surgery, there was no statistically significant difference in postoperative RLN paralysis rates between neurophysiologic monitoring and no monitoring groups.

In our study, the potential benefit of a continuous nerve-monitoring system was evaluated through a retrospective review of a single senior surgeon's cases. Our study is different from previous ones that sought to evaluate the rates of paralysis with and without monitoring in that over 1000 nerves were analyzed, while a relatively constant technique was maintained. We did not evaluate a compilation of multi-institutional and multiple-surgeon data.

It has been observed that an anatomically intact nerve does not always correlate with normal vocal fold function and that the absence of signal does not necessarily imply nerve dysfunction.[1,3] Proponents of continuous nerve monitoring have suggested that the unintended traction on the nerve, as may occur during dissection, can be noted and paresis rates thereby decreased. While the percentage of postoperative vocal cord paresis was found to be slightly lower with continuous nerve monitoring in this study, this difference was not found to be statistically significant. The results of the study also indicate that there was no significant difference in the rates of complete paralysis between the 2 groups in either the immediate postoperative period or in subsequent follow-up examinations. Furthermore, no significant decrease in the rate of temporary or permanent laryngeal nerve injury was observed with nerve monitoring.

A limitation of our study is its retrospective nature. As this was not a randomized study, complete elimination of patient selection bias was not possible. However, in an attempt to eliminate bias as best as possible, we did not intentionally allocate patients to one group or the other. Nerve monitoring was not performed prior to 2002 but was used routinely subsequent to that, unless the appropriate nerve-monitoring system was not available. We recognize the potential for some bias in this type of before-and-after comparison because of the possibility of improvement in the surgeon's experience over time. However, this should not significantly influence the results because the senior surgeon had already been performing thyroidectomies since 1991, and this retrospective cohort was from 1998 to 2005. The fact that this study could not prove any statistically significant difference between the 2 groups may be related to a very low complication rate—0.3% permanent paralysis rate in each group. It would require an even greater sample size or higher complication rates to show statistical significance. One can deduce from the results of this study that in the hands of highly experienced surgeons, continuous nerve monitoring is unlikely to improve the RLN paralysis rate. These results are in agreement with those of Dralle et al,[2] who found that the incidence of permanent RLN paralysis was somewhat reduced with nerve monitoring only for the subgroup of patients who were operated on by surgeons who performed thyroidectomies in low volume (ie, <45 NAR/y).

The results from this study do not necessarily imply that RLN monitoring is not a useful tool in thyroid surgery. It can be used to quickly facilitate initial localization of the nerve.[14] Once the region of the tracheoesophageal groove has been exposed, the stimulator probe can be set at slightly higher stimulus intensity (ie, 1.0-1.5 mA) and used to "search" for the nerve. As one approaches the nerve with the probe, a dull stimulus signal can be heard. Dissection can then be performed in that specific location to expose the nerve. In addition, once the nerve is identified, it can be stimulated at lower stimulus intensity (0.5 mA) to confirm that it is indeed the RLN. Furthermore, RLNs have varying branching patterns and can divide into anterior and posterior branches, motor and sensory branches, well below the entrance into the larynx.[15] The stimulator can be used to confirm that the surgeon is not actually following the abductor or a sensory branch and thus help to avoid inadvertently cutting the major motor branch. At the end of the procedure, the RLN can also be stimulated at the most proximal exposed portion to confirm its integrity. A positive signal with stimulation at 0.5 mA correlates well with normal function postoperatively.

Monitoring of the RLN might also be useful in reoperative cases, for example, in cases of recurrence in the paratracheal compartment or recurrent goiters. Yarbrough et al[16] reported in their retrospective study that continuous nerve monitoring did not significantly decrease the rate of injury in reoperative cases. This patient population was not specifically addressed in our study, in that patients undergoing only a paratracheal node dissection were excluded from our data set. Our experience is that the nerve-monitoring system is occasionally useful for stimulation of the nerve to differentiate nerve from scar tissue in reoperative cases. It did not necessarily prevent the neurapraxia type of injury from dissection of the nerve through scar tissue.

Disadvantages associated with continuous nerve monitoring include cost and the potential for having a false sense of security. Lack of electrical signal does not necessarily always indicate that the nerve is being stimulated, either by the stimulator or from trauma. Lack of stimulated EMG signals can certainly indicate that the structure being stimulated is not the RLN or that the nerve is transected or neurapraxic (true negative). However, it may also mean that the electrodes are not in the proper position in relationship to the vocal cords (false negative). This can result from the tube advancing too far inferiorly or superiorly or from rotation. Therefore, if one is convinced that the RLN has been identified but cannot obtain an EMG signal with electrical stimulation, it is prudent to check the tube position. One can also obtain false-positive signals with electrical stimulation if the endotracheal tube is placed too inferiorly such that all of the exposed surface electrodes are below the vocal cords. In this situation, if the probe is used to stimulate near the upper trachea, a dull signal can be obtained from direct transmission of the stimulus current through the posterolateral tracheal wall. Thus, one of the most important aspects of using the continuous RLN monitoring system is that the tube be positioned and secured in the proper position with the surface electrodes positioned along the vocal cords.

In conclusion, continuous nerve monitoring of the RLNs during thyroid surgery does not significantly reduce the incidence of postoperative vocal fold paresis or paralysis in the hands of an experienced surgeon. However, there are some useful applications of the nerve-monitoring system.

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