REVIEW

# Neuromonitoring in thyroid surgery

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**Purpose of review**
Laryngeal nerve injuries are among the most important complications of thyroidectomy. Recently, the use of neuromonitoring has been increasingly employed in order to predict and document nerve function at the end of thyroidectomy.

**Recent findings**
There is much controversy in recent studies concerning neuromonitoring in thyroid surgery. Some authors believe that the method does not bring any additional reduction in the paralysis rate of the laryngeal nerves. Other researchers defend its use only in selected cases and in very specific situations. Finally, some much respected surgeons advocate the routine use of neuromonitoring in all thyroidectomies.

**Summary**
In this review, we try to present relevant recent publications dealing with this still controversial subject, emphasizing the advantages and disadvantages of neuromonitoring in thyroidectomy.

**Keywords**
facial nerve, laryngeal nerves, nerve monitoring, parotidectomy, thyroidectomy

## INTRODUCTION

Laryngeal nerve injuries are, together with hypoparathyroidism, the most important complications that may occur during operations involving the thyroid gland [1]. In fact, in a published analysis of 33 cases of malpractice litigation in which the alleged negligence occurred after thyroidectomy, 15 (46%) involved an inferior laryngeal nerve (ILN) injury [2]. Curiously, nerve monitoring was not mentioned in any of these cases. Nevertheless, during the last decade, there has been a trend toward increased use of some form of nerve monitoring in thyroid surgery in the US. Horne *et al.* [3] sent a questionnaire to 1685 surgeons in the US. A total of 685 (40.7%) of the questionnaires were returned, and 81% of the respondents reported performing thyroidectomy. About 44.9% of these respondents used nerve monitoring during the operation, but only 28.6% reported using intraoperative monitoring for all cases. Respondents were 3.14 times more likely to currently use intraoperative monitoring if they had used it during their training.

A distinction between nerve stimulation and nerve monitoring needs to be established. During a thyroidectomy, nerve stimulators can be employed to verify the integrity of both superior and ILN, albeit the effect of the stimulation is not always so easy to access. The stimulation of the external branch of the superior laryngeal nerve (EBSLN) produces a contraction of the cricothyroid muscle, which can be readily visualized within the operative field. It is used to identify the nerve before dissecting the superior thyroid vessels, as well as to evaluate its function after mobilizing the superior thyroid pole [4]. On the contrary, the effect of the stimulation of the ILN is more difficult to check without laryngoscopy. Otto and Cochran [5] described a simple maneuver: the palpation of the interarytenoid area. When an intact recurrent nerve is stimulated, a twitch is immediately felt, due to the contraction of the ipsilateral posterior cricoarytenoid muscle. Randolph *et al.* [6] stated that this maneuver can even serve as a double check for a doubtful positive nerve monitoring result. The obvious advantage of the nerve monitoring is to add an objective record of the contraction of the laryngeal muscles secondary to the nerve stimulation, before and after the dissection of the laryngeal nerves.

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## KEY POINTS

- Laryngeal nerve injury is one of the most frequent complications of thyroidectomy.
- Nerve monitoring of the laryngeal nerves is the only objective way to document an intact nerve at the end of a lobectomy.
- The surgeon should consider postponing the performance of the contralateral lobectomy when a nonfunctioning nerve is found at the end of a lobectomy, to avoid bilateral vocal fold paralysis.
- The negative predictive value of nerve monitoring is very high, but the positive predictive value is lower.
- Continuous vagal stimulation offers a real prospect of preventing the injury of the recurrent laryngeal nerve.

What are the objectives of nerve monitoring in thyroid surgery? According to Dralle *et al*. [7], in their excellent systematic review, there are three main goals: first, to offer better assessment of the possible anatomic variations of the recurrent laryngeal nerves, like extralaryngeal branching or nonrecurrent ILN [8] (and, we could add, an abnormally low EBSLN, type 2b in the classification we have previously published [9]); second, to provide intraoperative documentation of the ILN function, even in unfavorable situations, like reoperations with only one functioning nerve; third, to differentiate between voice changes secondary to recurrent nerve trauma and those unrelated to the operation.

What is the actual role of laryngeal nerve monitoring in thyroid surgery? Is it necessary in all cases? Does it actually decrease the rate of both inferior and superior laryngeal nerve paralysis?

The purpose of this review is to offer a critical review of some important publications on this very relevant subject.

## WHICH SYSTEM TO USE?

In 1984, Woltering *et al*. [10] reported a system for recurrent nerve stimulation with mean amperage of 1.3 mA, utilizing a double-cuffed endotracheal tube to monitor the contraction of the thyroarytenoid muscle. In a series of 12 patients, positive nerve identification was obtained in all cases, with normal postoperative laryngoscopic findings.

Some years later, Mermelstein *et al*. [11] described the use of electrodes attached to the endotracheal tube and in close contact with the vocal folds in a series of 28 patients submitted to thyroid and parathyroid operations.

The most widely used system is the Nerve Integrity Monitoring (NIM) system (Nerve Monitoring Systems, Medtronic, MN, USA). Introduced by Lamadé *et al*. [12,13] in 1996 and 1997, it has gained increasing popularity among surgeons during the last decade through the work of Randolph *et al*. [14,15]. Two surface electrodes, embedded into an endotracheal tube, remain in contact with the vocal folds throughout the whole operation. With the patient receiving no paralyzing drugs, a probe can be used by the surgeon to search and to positively identify the ILN and, eventually, the EBSLN, through an electrical stimulus from 0.5 to 2.0 mA. After a latency period, which is measured, a contraction of the vocal fold is produced and can be detected by the electrodes and transmitted to a monitor. The resulting waveform complex can then be quantified and, most importantly, recorded. At the end of the lobectomy, the stimulation is repeated and both the latency time and the magnitude of the electrical wave are recorded and compared with those obtained at the beginning of the dissection. Some authors prefer to perform a direct stimulation of the vagus nerve, with the advantage of a positive evaluation of the whole length of the recurrent nerve, identifying possible injuries located inferiorly to the stimulation point. In fact, the most reliable way to prove laryngeal nerve integrity at the end of a thyroidectomy is ipsilateral vagal nerve stimulation [16▪]. Thomusch *et al*. [17] reported a prospective multi-institutional study comparing the specificity of vagal nerve stimulation with the direct recurrent nerve stimulation, including 15 403 nerves at risk. There was a statistically significant difference in favor of the vagal nerve stimulation ($P < 0.05$).

There are other methods to verify the ILN integrity during a thyroidectomy, like concomitant intraoperative videolaryngoscopy or even placing an electrode in the true vocal fold through the cricothyroid membrane, but they are used by a minority of surgeons [2]. Hermann *et al*. [18] reported recurrent nerve monitoring using the Neurosign 100 device (Magstim Company Limited, UK) by transligamental placement of the recording electrode into the vocalis muscles.

## DOES NERVE MONITORING REDUCE THE RATE OF INFERIOR LARYNGEAL NERVE DAMAGE DURING THYROIDECTOMY?

Several experts believe that nerve monitoring during a thyroidectomy can actually help to identify the laryngeal nerves, especially in selected circumstances. However, in spite of the evident benefits, many authors failed to demonstrate that the method added an objective improvement in the rates of nerve function preservation at the end of the operation.

Beldi *et al.* [19] analyzed the usefulness of intraoperative nerve monitoring in a series of 288 thyroidectomies. They concluded that the use of monitoring did not lower the incidence of ILN paralysis.

Snyder and Hendricks [20] prospectively evaluated 100 patients submitted to thyroidectomy, comprising 185 ILNs. The use of nerve monitoring helped the surgeon to find the nerve only when there was a positive electromyographic (EMG) response. In their experience, it did not prevent recurrent nerve transection.

Robertson *et al.* [21] published a cohort study comparing 116 recurrent nerves at risk monitored with the NIM system with 120 nonmonitored nerves. Temporary ILN paresis was observed in 4.24% of the nerves in the control group and 3.45% of those in the monitored group ($P=0.89$), showing no reduction in the frequency of nerve injury.

Witt [22] studied a series of 136 patients undergoing thyroidectomy, with a total of 190 ILNs at risk. He found no difference in the frequency of recurrent nerve paresis or paralysis comparing a group of 107 unmonitored nerves with 83 monitored nerves, and concluded that nerve monitoring did not reduce the incidence of nerve injury.

Netto Ide *et al.* [23] performed a cohort study in a series of 104 patients who underwent thyroidectomy with nerve monitoring and were compared with 100 patients operated without monitoring. The frequency of nerve injury was 6.8 and 7.5%, respectively, with no statistical difference. They concluded that the use of intraoperative nerve monitoring did not decrease the rate of postoperative vocal fold immobility.

Shindo and Chheda [24] evaluated the importance of nerve monitoring in a cohort of 684 patients, comprising 1043 ILNs at risk. The incidence of unilateral vocal cord paresis 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 conclusion was that nerve monitoring did not reduce the incidence of postoperative vocal cord paralysis.

Atallah *et al.* [25] analyzed the use of nerve monitoring in a series of patients submitted to what was considered 'high-risk' thyroidectomy, using nonmonitored nerves as controls. Transient and permanent nerve dysfunction rates were noted in both groups (8.8% of temporary paralysis in the monitored group, in comparison with 9.1% in the unmonitored group; 3.9% of nerves at risk in the monitored group, in comparison with 3.8% in the unmonitored group). In conclusion, nerve monitoring offered no additional benefit for patients undergoing 'high-risk' thyroidectomy.

Dralle *et al.* [26] reported a prospective multi-institutional study in which 16 448 patients comprising 29 998 ILNs at risk were evaluated. They were divided into three groups, according to the approach to the ILN: group 1, no ILN identification; group 2, visual ILN identification; and group 3, visual ILN identification and EMG monitoring, employing a bipolar needle electrode inserted in the thyroarytenoid muscle. Among the risk factors for nerve injury, when the ILN was not identified, there was a 40% increase in the rate of nerve injury (odds ratio 1.4). However, no difference was observed between the first two groups. Visual nerve identification was considered the gold standard to avoid ILN injury.

One study found an objective benefit in nerve monitoring. Barczyński *et al.* [27] performed a prospective trial involving 1000 patients undergoing total thyroidectomy, randomized in two groups: one group with nerve monitoring and the control group with standard visual identification. Transient injury was noted in 38 of 500 nonmonitored nerves, compared with 18 of 500 monitored nerves, and this difference was statistically significant ($P=0.011$). Permanent injury occurred in 12 of 500 ILNs in the nonmonitored nerve group, compared with eight of 500 ILNs in the monitored nerve group, but this difference was not significant ($P=0.368$). They concluded that the use of nerve monitoring decreased the incidence of transient but not permanent recurrent nerve paresis compared with visualization alone, particularly in high-risk patients.

When observing absence of signal at the end of a lobectomy, the surgeon should seriously consider not performing the contralateral lobectomy, in order to avoid bilateral vocal fold immobility, which usually requires a tracheostomy. According to some authors, this should be considered presently the main reason to utilize nerve monitoring during a thyroidectomy [17,28].

## PITFALLS IN LARYNGEAL NERVE MONITORING

Dralle *et al.* [7] pointed out some of the pitfalls during the use of nerve monitoring in thyroidectomy that may impair the adequate intraoperative assessment of vocal fold motion.

The main technical pitfall is inadequate placement or displacement of the endotracheal tube, resulting in loss of contact between the vocal fold and the surface electrode. In the absence of signal, it is important to visually check the tube position with a fiberoptic scope, and it is useful to make some vertical and horizontal marks with a permanent-inked pen on the tube before its insertion to facilitate this visual check. It is also important to verify if there is any loose connection between the electrodes and the monitoring system.

The anesthesiologist must avoid the use of paralyzing agents, which can block the contraction of the vocalis muscle even when an intact nerve is stimulated. Also, there are traumatic complications related to the intubation and the extubation process that may cause vocal fold immobility (arytenoid subluxations and cuff-related injuries, among others).

Finally, Dralle *et al*. [7] mentioned the possibility of pitfalls related to other factors, like laryngeal edema or the use of corticosteroids, which may lead to discrepant findings.

## NEGATIVE AND POSITIVE PREDICTIVE VALUES OF INFERIOR LARYNGEAL NERVE MONITORING IN THYROIDECTOMY

The efficacy of a method can be measured by its negative and positive predictive values (NPV and PPV, respectively). Considering postoperative videolaryngoscopy as the gold standard to establish the status of vocal fold mobility, a nerve monitoring true negative evaluation at the end of a lobectomy means a normal contact EMG with a normally mobile vocal fold, false negative means normal signal with a paralyzed vocal fold, true positive means absence of signal and a paralyzed vocal fold and false positive means absence of signal and a normally mobile vocal fold.

Some authors analyzed these parameters in their studies. Most reported very high NPV for the inferior laryngeal nerve monitoring in thyroidectomy, varying from 91.0 to 100% [7,15,16■,17,29,30]. Therefore, when a positive contraction of the vocalis muscle was obtained when stimulating the recurrent nerve at the end of a lobectomy, it was almost invariably associated with a normal functioning nerve at the postoperative laryngoscopic evaluation. Conversely, these same authors observed very low PPV for nerve monitoring, ranging from 10.0 to 57.1% [7,15,16■,17,29,30], particularly concerning permanent vocal fold paralysis. We published our own results in a series of 447 patients submitted to thyroidectomy between 2001 and 2008. There were 868 nerves at risk; 858 nerves (98.8%) presented normal videolaryngoscopic features postoperatively. At the late videolaryngoscopy, there were only two permanent nerve paralyses (0.2%). Nerve monitoring showed abnormal electrical activity in 25 of 868 nerves (2.9%), including all 10 endoscopically compromised nerves, with 15 false positive nerves. There were no false negative nerves. Therefore, PPV was 40.0% and NPV was 100% [31■■].

## NORMATIVE VALUES IN NERVE MONITORING OF THE INFERIOR LARYNGEAL NERVE

Randolph [32■■] was the principal investigator of an international collaborative study that established guidelines for nerve monitoring in thyroidectomy, including the normative values for ILN stimulation during thyroidectomy. The threshold for stimulation should be 1 mA. The normal latency between the stimulation and the first evoked waveform was 3.97 ms and the amplitude of the waveform could vary from 100 to 800 μV, according to values obtained during normal awake voluntary speech. Loss of signal or amplitude of the waveform inferior to 100 μV after 1–2 mA stimulus should be strongly predictive of ILN damage, after checking for proper function of the whole system.

## NERVE MONITORING OF THE EXTERNAL BRANCH OF THE SUPERIOR LARYNGEAL NERVE

We demonstrated that nerve stimulation was crucial for the positive identification of the EBSLN during thyroidectomy, especially in the type 2b nerves [4]. Some authors suggested that nerve monitoring might help to identify the EBSLN. Timon and Rafferty [33] used the Neurosign system to search for the EBSLN in 21 cases. Jonas and Bähr [34] implanted bipolar electrodes in the cricothyroid muscle in 108 patients, stimulating the nerve with 0.3–1.0 mA. They concluded that nerve monitoring helped not only to localize the nerve but also to assure its integrity at the end of the lobectomy.

## PROSPECTS

With the increasing acceptance of nerve monitoring in thyroid surgery, the next step is to prove that it can actually predict the possible injury of the ILN before it happens, actually interrupting the hazardous maneuver that the surgeon is performing. The most promising method to achieve this goal is to install a stimulating electrode around the vagus nerve [35,36] previously to starting the dissection of the thyroid lobe and to maintain a continuous vagal stimulation, closely monitoring the latency and the waveform of the ILN. Ongoing studies are trying to establish this method as the gold standard for real prevention of ILN injury during a thyroidectomy.

## CONCLUSION

Despite the absence of studies with high evidence level, the use of nerve monitoring is advisable in thyroid surgery, especially in some specific situations, like very large goiters, reoperations, massive metastatic disease on levels VI and VII, among others. The most important contribution that this method can offer is to ensure neurophysiological integrity of an ILN at the end of a lobectomy before going to the other side, thus avoiding the terrible possibility of a bilateral vocal fold paralysis.


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### Conflicts of interest

*None of the authors has any conflict of interest concerning the subject of this manuscript.*

## REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
▪ of special interest
▪▪ of outstanding interest
Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 150).


1. Cernea CR, Brandão LG, Hojaij FC, *et al.* How to minimize complications in thyroid surgery? Auris Nasus Larynx 2010; 37:1–5.
2. Abadin SS, Kaplan EL, Angelos P. Malpractice litigation after thyroid surgery: the role of recurrent laryngeal nerve injuries 1989–2009. Surgery 2010; 148:718–722.
3. Horne SK, Gal TJ, Brennan JA. Prevalence and patterns of intraoperative nerve monitoring for thyroidectomy. Otolaryngol Head Neck Surg 2007; 136:952–956.
4. Cernea CR, Ferraz AR, Furlani J, *et al.* Identification of the external branch of the superior laryngeal nerve during thyroidectomy. Am J Surg 1992; 164:634–639.
5. Otto RA, Cochran CS. Sensitivity and specificity of intraoperative recurrent laryngeal nerve stimulation in predicting postoperative nerve paralysis. Ann Otol Rhinol Laryngol 2002; 111:1005–1007.
6. Randolph GW, Kobler JB, Wilkins J. Recurrent laryngeal nerve identification and assessment during thyroid surgery: laryngeal palpation. World J Surg 2004; 28:755–760.
7. Dralle H, Sekulla C, Lorenz K, *et al.* German IONM study group. Intraoperative monitoring of the recurrent laryngeal nerve in thyroid surgery. World J Surg 2008; 32:1358–1366.
8. Cernea CR, Hojaij FC, De Carlucci D Jr, *et al.* Recurrent laryngeal nerve: a plexus rather than a nerve? Arch Otolaryngol Head Neck Surg 2009; 135:1098–1102.
9. Cernea CR, Ferraz AR, Nishio S, *et al.* Surgical anatomy of the external branch of the superior laryngeal nerve. Head Neck 1992; 14:380–383.
10. Woltering EA, Dumond D, Ferrara J, *et al.* A method for intraoperative identification of the recurrent laryngeal nerve. Am J Surg 1984; 148:438–440.
11. Mermelstein M, Nonweiler R, Rubinstein EH. Intraoperative identification of laryngeal nerves with laryngeal electromyography. Laryngoscope 1996; 106:752–756.
12. Lamadé W, Fogel W, Rieke K, *et al.* Intraoperative monitoring of the recurrent laryngeal nerve. A new method [in German]. Chirurg 1996; 67:451–454.
13. Lamadé W, Meyding-Lamadé U, Hund E, *et al.* Transtracheal monitoring of the recurrent laryngeal nerve. Prototype of a new tube [in German]. Chirurg 1997; 68:193–195.
14. Randolph GW. Surgical anatomy of the recurrent laryngeal nerve. In: Randolph GW, editor. Surgery of thyroid and parathyroid glands. Philadelphia: Elsevier; 2003. pp. 300–342.
15. Lesnik DJ, Brandão LG, Randolph GW. Recurrent laryngeal nerve monitoring in thyroid and parathyroid surgery: technique for the NIM 2 system. In: Cernea CR, Myers EN, Dias FL, *et al.*, editors. Pearls and pitfalls in head and neck surgery: practical tips to minimize complications. Basel: Karger; 2008. pp. 4–5.
16. Chiang FY, Lee KW, Chen HC, *et al.* Standardization of intraoperative ▪ neuromonitoring of recurrent laryngeal nerve in thyroid operation. World J Surg 2010; 34:223–229.

This study offers suggestions to standardize the intraoperative laryngeal nerve monitoring during a thyroidectomy.

17. Thomusch O, Sekulla C, Machens A, *et al.* Validity of intra-operative neuromonitoring signals in thyroid surgery. Langenbecks Arch Surg 2004; 389:499–503.
18. Hermann M, Hellebart C, Freissmuth M. Neuromonitoring in thyroid surgery: prospective evaluation of intraoperative electrophysiological responses for the prediction of recurrent laryngeal nerve injury. Ann Surg 2004; 240:9–17.
19. Beldi G, Kinsbergen T, Schlumpf R. Evaluation of intraoperative recurrent nerve monitoring in thyroid surgery. World J Surg 2004; 28:589–591.
20. Snyder SK, Hendricks JC. Intraoperative neurophysiology testing of the recurrent laryngeal nerve: plaudits and pitfalls. Surgery 2005; 138:1183–1191.
21. Robertson ML, Steward DL, Gluckman JL, *et al.* Continuous laryngeal nerve integrity monitoring during thyroidectomy: does it reduce risk of injury? Otolaryngol Head Neck Surg 2004; 131:596–600.
22. Witt RL. Recurrent laryngeal nerve electrophysiologic monitoring in thyroid surgery: the standard of care? J Voice 2005; 19:497–500.
23. Netto Ide P, Vartanian JG, Ferraz PR, *et al.* Vocal fold immobility after thyroidectomy with intraoperative recurrent laryngeal nerve monitoring. Sao Paulo Med J 2007; 125:186–190.
24. Shindo M, Chheda NN. Incidence of vocal cord paralysis with and without recurrent laryngeal nerve monitoring during thyroidectomy. Arch Otolaryngol Head Neck Surg 2007; 133:481–485.
25. Atallah I, Dupret A, Carpentier AS, *et al.* Role of intraoperative neuromonitoring of the recurrent laryngeal nerve in high-risk thyroid surgery. J Otolaryngol Head Neck Surg 2009; 38:613–618.
26. Dralle H, Sekulla C, Haerting J, *et al.* Risk factors of paralysis and functional outcome after recurrent laryngeal nerve monitoring in thyroid surgery. Surgery 2004; 136:1310–1322.
27. Barczyński M, Konturek A, Cichoń S. Randomized clinical trial of visualization versus neuromonitoring of recurrent laryngeal nerves during thyroidectomy. Br J Surg 2009; 96:240–246.
28. Goretzki PE, Schwarz K, Brinkmann J, *et al.* The impact of intraoperative neuromonitoring (IONM) on surgical strategy in bilateral thyroid diseases: is it worth the effort? World J Surg 2010; 34:1274–1284.
29. Chan WF, Lo CY. Pitfalls of intraoperative neuromonitoring for predicting postoperative recurrent laryngeal nerve function during thyroidectomy. World J Surg 2006; 30:806–812.
30. Tomoda C, Hirokawa Y, Uruno T. Sensitivity and specificity of intraoperative recurrent laryngeal nerve stimulation test for predicting vocal cord palsy after thyroid surgery. World J Surg 2006; 30:1230–1233.
31. Cernea CR, Brandão LG, Hojaij FC, *et al.* Negative and positive predictive ▪▪ values of nerve monitoring in thyroidectomy. Head Neck 2011. doi: 10.1002/hed.21695. [Epub ahead of print]

In this study, we analyzed one of the largest series of consecutive patients treated by a single group of surgeons, highlighting the very high negative–positive value of intraoperative nerve monitoring of the inferior laryngeal nerve during thyroidectomy, critically evaluating the causes of the false positive cases we observed.

32. Randolph GW, Dralle H, International Intraoperative Monitoring Study Group. ▪▪ Electrophysiologic recurrent laryngeal nerve monitoring during thyroid and parathyroid surgery: international standards guideline statement. Laryngoscope 2011; 121:S1–S16.

In this outstanding multinational multi-institutional study, Randolph and Dralle establish the guidelines for the proper use of nerve monitoring in thyroid surgery, reaching details such as positioning of the endotracheal tube, intensity of the electrical stimulation and amplitude of the complex, among others. A very important source for all surgeons interested in the field.

33. Timon CI, Rafferty M. Nerve monitoring in thyroid surgery: is it worthwhile? Clin Otolaryngol Allied Sci 1999; 24:487–490.
34. Jonas J, Bähr R. Neuromonitoring of the external branch of the superior laryngeal nerve during thyroid surgery. Am J Surg 2000; 179:234–236.
35. Schneider R, Przybyl J, Hermann M, *et al.* A new anchor electrode design for continuous neuromonitoring of the recurrent laryngeal nerve by vagal nerve stimulations. Langenbecks Arch Surg 2009; 394:903–910.
36. Schneider R, Przybyl J, Pliquett U, *et al.* A new vagal anchor electrode for real-time monitoring of the recurrent laryngeal nerve. Am J Surg 2010; 199:507–514.