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ORIGINAL ARTICLE – ENDOCRINE TUMORS

Use of the Nerve Integrity Monitor during Thyroid Surgery Aids Identification of the External Branch of the Superior Laryngeal Nerve

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ABSTRACT

Background. The external branch of the superior laryngeal nerve (EBSLN) is at risk during thyroid surgery. Despite meticulous dissection and visualization, the EBSLN can be mistaken for other structures. The nerve integrity monitor (NIM) allows EBSLN confirmation with cricothyroid twitch on stimulation.

Aims. The aim of this study was to assess any difference in identification of EBSLN and its anatomical sub-types by dissection alone compared to NIM-aided dissection.

Methods. Routine intra-operative nerve monitoring (IONM) was used, when available, for 228 consecutive thyroid operations (129 total thyroidectomies, 99 hemi-thyroidectomies) over a 10-month period. EBSLN identification by dissection alone (with NIM confirmation of cricothyroid twitch) and by NIM-assisted dissection was recorded prospectively. Anatomical sub-types were defined by the Cernea classification.

Results. Of 357 nerves at risk, 97.2 % EBSLNs (95 % confidence interval [CI], 95.5–98.9) were identified by visualization and NIM-aided dissection compared to 85.7 % (95 % CI, 82.1–89.3) identified by dissection alone (<0.001). EBSLN frequency was 34 % for type 1, 55 % for type 2a, and 11 % for type 2b. All identified EBSLNs were stimulated to confirm a cricothyroid twitch after superior thyroid vessel ligation.

Conclusion. Using the NIM and meticulous dissection of the upper thyroid pole improves EBSLN identification. As the EBSLN is at risk during thyroidectomy and can lead to voice morbidity, the NIM can aid identification of the EBSLN and provide a functional assessment of the EBSLN after thyroid resection.

The external branch of the superior laryngeal nerve (EBSLN) is the sole motor supply of the cricothyroid muscle and is closely associated with the superior thyroid vasculature, causing it to be at risk during thyroid surgery. The cricothyroid muscle contracts and increases the tension of the adducted ipsilateral vocal cord, and injury can result in altered voice frequency and vocal projection, which is especially important in voice professionals. In the previous literature, it has been reported that identification of up to 90 % of EBSLNs are at risk during thyroidectomy[1]; however, visual identification alone can lead to mistaking the EBSLN for non-neural fibers or tendinous muscle fibers, thereby overestimating rates of identification.[2] The use of the nerve integrity monitor (NIM) allows for nerves to be identified and confirmed by functional assessment during surgery. International Neural Monitoring Study Group guidelines have suggested that the gold standard of EBSLN identification should be visual, along with a cricothyroid twitch on stimulation and/or presence of electromyographic glottis response of vocal cord depolarization identified on surface endotracheal tube electrode arrays.[3]

The aim of this study was to quantify identification of the EBSLN by visualisation alone compared to visualisation aided by use of the NIM to determine if the NIM provides additional data to visualisation to minimise EBSLN injury.

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METHODS

A prospective study of consecutive patients undergoing total or hemi-thyroidectomy by a specialist endocrine surgeon was performed where the NIM was available for use. Data was collected and stored in a dedicated database with approval from the Northern Sydney Area ethics committee. All patients were referred for pre-operative vocal cord examination by laryngoscopy. Patients were excluded from the study if a pre-existing vocal cord palsy was found. Primary outcome measures were identification of the nerve by visualisation alone compared to NIM-assisted identification, with confirmation of all nerves by eliciting a cricothyroid twitch on NIM stimulation. Secondary outcomes were identification and incidence of EBSLN anatomical sub-types. EBSLN sub-types were classified by the Cernea classification, which classifies the EBSLN by a horizontal plane 1 cm above the upper thyroid pole. The type 1 nerves cross the superior thyroid vessels above the horizontal plane. The type 2a nerves cross the vessels less than <1 cm above the plane, but above the upper thyroid pole. type 2b nerves cross the vessels below the plane and below the upper thyroid pole.[4]

OPERATIVE TECHNIQUE

Thyroidectomy was performed in a standardised way by the senior author (specialist endocrine surgeon) or specialist endocrine surgical fellows under supervision with routine transverse division of the sternothyroid and sternohyoid muscles, preservation of the ansa cervicalis, and use of the LigaSure thermal sealing system (Covidien, Mansfield, MA), which has been previously described.[5] Thyroidectomy was performed under general anaesthesia, using short-acting muscle relaxants at induction with intraoperative nerve monitoring (IONM) using the NIM 2.0/3.0 systems (Medtronic, Jacksonville, FL) and the NIM Tri-Vantage electromyography (EMG) endotracheal tube. A standardised technique of IONM was used, with testing of the vagal response(s) at the beginning and end of each operation.[3] After the resection of the thyroid, the sternothyroid and sternohyoid muscles were re-approximated with a running absorbable suture.

EBSLN Identification and Data Collection

The EBSLN was recorded as being identified by visual identification alone or NIM-assisted identification. First, an attempted visualisation of the EBSLN was made by retraction of the upper thyroid lobe laterally and caudally to open the avascular space between the medial aspect of the superior pole and the cricothyroid muscle. This area was carefully dissected to visually identify the EBSLN, and if confidently identified, it was stimulated with 1.0 mA electrical current using the NIM mono-polar probe. On stimulation, if strong and simultaneous contraction of the pars recta and pars oblique components of the cricothyroid muscle was observed (Supplementary Video File 1), then the presumed EBSLN was confirmed and a result of EBSLN that was identified by visual identification alone was recorded (NIM did not aid identification).

Sometimes stimulating what was believed to be the EBSLN did not elicit a cricothyroid twitch, or only a partial contraction of the cricothyroid muscle occurred, and then visual identification alone was recorded as negative and the presumed nerve was considered to be a non-neural structure (blood vessel/muscle fibre/connective tissue). From this point on, identification of the EBSLN was considered to be NIM-assisted, either by toggling between the thyroid upper pole and cricothyroid sub-fascial structures to elicit a strong cricothyroid twitch or by stimulating further structures around the upper pole to elicit a cricothyroid twitch.

If no cricothyroid twitch was found on stimulation after further dissection, this was recorded as no EBSLN identified and the EBSLN was presumed to be high above the upper thyroid pole.

If the EBSLN was confirmed, the nerve was protected with saline soaked pledgets to reduce the risk of thermal injury, and the branches of the superior thyroid vessels were sealed and divided with the LigaSure thermal sealing system (Covidien). If the possibility of thermal spread to the EBSLN was of concern, the superior thyroid vessels were ligated by suture. After individual ligation of the branches of the superior thyroid vessels, repeat nerve conduction of the EBSLN was performed stimulating the nerve proximal to the point of the nearest thermal seal of a superior thyroid artery branch.

Post-operative Voice Analysis

All patients were reviewed at 1 month after surgery by the operative surgeon. All patients were asked if they had noticed any voice change after their surgery and the nature of the change, if applicable. All patients were referred for a post-operative vocal cord check by an experienced ear, nose, and throat surgeon.

Statistical Analysis

Data was analysed using SPSS Statistics, release 21 (IBM Corp., Armonk, NY). Categorical variables were compared using the McNemar test and continuous variables by the analysis of variance (ANOVA) test. Statistical significance was set at $p \leq 0.05$. Sample size estimation

TABLE 1 Demographics and indications for surgery

Demographics (%)	Total ($n = 228$)
Female	182 (79.8)
Mean age (years)	54
Surgery indication	
Multi-nodular goitre	133 (58.3)
Malignancy	46 (20.2)
Thyrotoxicosis	31 (13.6)
Sub-sternal goitre	15 (6.6)
Other	3 (1.3)
Procedure performed	
Total thyroidectomy	129 (56.6)
Hemi-thyroidectomy	99 (43.4)
Thyroidectomy with lymph node dissection	28 (7.8)
Thyroidectomy with parathyroidectomy	18 (5.0)
Mean thyroid weights (range)	
Total thyroidectomy	53.4 g (7–309)
Hemi-thyroidectomy	28.7 g (4–160)

TABLE 2 EBSLN identification ($n = 357$)

	EBSLN identified (95 % CI)	
Visual identification alone (NIM did not aid identification)	85.7 % (82.1–89.3)	$p < 0.001$
NIM-assisted identification	97.2 % (95.5–98.9)	

CI confidence interval, *EBSLN* external branch of the superior laryngeal nerve, *NIM* nerve integrity monitor

showed a minimum of 97 nerves at risk was required for 90 % power, assuming a 10 % difference in identification.

RESULTS

Between May 2013 and March 2014, 228 thyroidectomies (129 total thyroidectomies and 99 hemi-thyroidectomies) were performed using the NIM, causing 357 EBSLNs to be at risk (183 left EBSLNs and 174 right EBSLNs). Surgery was mainly performed for primary thyroid procedures with 8.5 % of cases being for secondary or re-do procedures. Patient demographics and indications for surgery are shown in Table 1.

Of the 357 nerves at risk, 347 (97.2 %) nerves were identified by visualisation with NIM confirmation of a cricothyroid twitch. Initial dissection and visualisation (NIM did not aid identification) correctly identified 306 (85.7 %) nerves at risk. As shown in Table 2, use of the NIM led to a significant improvement in EBSLN identification. Ten (2.8 %) nerves were unable to be identified, one of which was due to technical problems with conduction of the NIM electrical circuit and nine due to no nerve being found, despite careful dissection of the upper thyroid pole. These nerves were presumed to be high type 1 nerves existing above the operative field. Thirty (8.4 %) nerves were identified as being in a sub-fascial location and were only identified with the use of the NIM. After superior thyroid vessel ligation, conduction was tested by stimulation of the EBSLN with no loss of cricothyroid twitch.

TABLE 3 EBSLN identification by NIM confirmation for anatomical sub-types and thyroid weights ($n = 326$)

Sub-type	Incidence (%)	Dissection initially confirmed (95 % CI)	p value	Mean weights (g) (95 % CI)
Cernea type 1	34.4	70.5 % (62.1–79.0)*	<0.001	25.8 (20.3–31.3)
Cernea type 2-a	54.6	97.8 % (95.6–99.9)	0.063	24.6 (21.0–28.3)
Cernea type 2-b	11.0	91.7 % (82.6–100)	0.25	46.8 (32.5–61.2)*

CI confidence interval, *EBSLN* external branch of the superior laryngeal nerve, *NIM* nerve integrity monitor

* $p \leq 0.05$

Data was collected for the EBSLN anatomical sub-types on 326 nerves. Table 3 shows the incidence and identification of each sub-type compared to nerves identified by dissection and NIM confirmation with cricothyroid twitch and the association with thyroid weight. Combining type 2a and 2b nerves for statistical and power analysis, dissection initially confirmed 96.7 % of type 2 nerves [95 % confidence interval (CI) 94.3–99.1; $p = 0.008$]. Type 2b nerves were associated with a significantly heavier thyroid specimen compared to type 1 and type 2a nerves ($p < 0.001$). For patients undergoing total thyroidectomy, 69.4 % displayed symmetry of EBSLN sub-type.

All 357 recurrent laryngeal nerves at risk were identified by dissection and function was confirmed by stimulation with the NIM in all but one case due to technical problems. Eight (2.2 %) recurrent laryngeal nerves suffered loss of signal during surgery, which were thought to be due to heat or traction injuries. For two patients, this loss of signal occurred during the first side of total thyroidectomy leading to a staged completion thyroidectomy. Both patients recovered well and underwent completion thyroidectomy within 3 months of initial surgery after fibre-optic laryngoscopy confirmation of returned vocal cord function. There were no false-positive or false-negative events involving the recurrent laryngeal nerve in this series.

Follow-up data was available for 251 of the 258 patients who underwent surgery, with a median follow-up of 1.1 months (range 1–9 months). Seventeen (6.8 %) patients complained of a change in their voice after surgery; this change ranged from a hoarse voice to voice fatigue to an inability to project their voice. Of the eight patients who suffered a loss-of-signal event of the recurrent laryngeal nerve during surgery, all initially reported a hoarse voice and seven were documented to have a vocal cord palsy at the post-operative vocal cord check, whereas the other patient had full vocal cord movement and normal voice at the time of formal assessment. The same seven patients subsequently recovered during further follow-up with no permanent cord palsies. The other nine patients who complained of a voice change did not have a vocal cord palsy and the cause of their voice change was not apparent.

For the 10 patients in whom the EBSLN was unable to be located at surgery, nine reported no voice change after surgery and no abnormalities were found at post-operative vocal cord check. The remaining patient suffered a loss of signal event of the recurrent laryngeal nerve at surgery and reported a hoarse voice after surgery, but was found to have normal functioning vocal cords at laryngoscopy and a normal voice 3 months after surgery.

DISCUSSION

IONM and the management of the EBSLN are both areas of controversy in thyroid surgery. Use of the NIM has been argued to add little to experienced thyroid surgeons, except added cost,[6] whereas the need to identify the EBSLN to avoid injury has being questioned with avoidance being reported as equally effective in preserving function.[7]

The incidence of permanent injury to the EBSLN after thyroid surgery ranges from 0.5 to 3.5 %,[7,8] whereas temporary injury rates of up to 58 % have been reported.[8] The variability of reported rates is due to the difficulty of quantifying EBSLN function, surgeon experience, and differences in diagnostic techniques.[8,9] Injury occurs to the EBSLN due to the close relationship of the nerve to the superior thyroid vessels, of which type 2 nerves are at the most risk.[4] This is especially important for patients undergoing surgery for large goitres who have a higher rate of type 2 nerves.[1,10] The widespread use of thermal sealing systems and the risk of thermal spread poses another argument to identify and preserve the nerve.[11] As with the recurrent laryngeal nerve, it would seem the best strategy to avoid EBSLN injury would involve its visualisation and protection.[12] This is most easily accomplished when the strap muscles are divided routinely, and if they are not then division of the laryngeal head of the sternothyroid muscle facilitates exposure.[3] However visualisation alone may not identify up to 20 % of the nerves that are sub-fascial, but whose course can be confirmed by the use of the NIM.[3,13]

The results of this study show that is possible for an experienced thyroid surgeon to identify and functionally preserve the EBSLN in more than 97 % of nerves at risk in a large variety of different thyroid pathologies when using IONM routinely. In this series, 14.3 % of EBSLNs were mistakenly identified by visualisation alone. The use of the NIM allowed an increased identification of the EBSLN by 11.5 %. As the improvement in identification in the EBSLN in this series were mainly for type 1 EBSLN, it could be argued that the results are not clinically significant, as these nerves would be at lesser risk of injury during ligation of the upper thyroid pole and avoidance of the EBSLN would have been sufficient. With the increasing use of thermal sealing devices during thyroid surgery, however, the possibility of lateral thermal spread injuring an unidentified "avoided" nerve is possible and therefore type 1 nerves are at risk of inadvertent injury. Significantly, the NIM allowed for the identification of 3.3 % of type 2 EBSLN, which would have been damaged had the operating surgeon relied on visualisation alone. These nerves were typically seen in patients with large goitres and lying behind upper pole vessels.

The visual identification rates of 86 % of EBSLN in this series are consistent with other studies with identification rates that range from 86 to 93 %[1,6] using similar operative techniques of division of the strap muscles. However, as these studies have not included IONM, functional confirmation of the EBSLN was not possible at the time of surgery. Other studies have demonstrated improvements in EBSLN identification after utilisation of the NIM (Table 4). Barczynski et al.[9] showed a significant improvement of EBSLN identification by use of the NIM from 34 to 83 % in a randomised controlled trial. This randomised study used a surgical technique of thyroidectomy that split, but did not divide the strap muscles, which may explain the difference in identification of the EBSLN compared to this series, with an identification rate of 97 %. For those surgeons who do not routinely divide the strap muscles, transverse division of at least the sternothyroid muscle can facilitates exposure of the avascular space of the sternothyroid-laryngeal triangle, which is widely exposed utilising a policy of routine strap muscle division and can lead to nerve identification in 90 % of cases.[14] No difference in post-operative voice quality has been found after sternothyroid muscle division.[15] A recent small study of 29 nerves at risk has shown an identification rate of 100 % EBSLN using IONM, along with quantifiable EMG responses by the nerve monitor using a muscle splitting technique, but not a dividing technique.[16] Quantifiable EMG responses can be seen in up to 80 % of nerves using IONM due to the presence of communicating nerves between the recurrent and EBSLN; however, although these responses were observed during this series, data was not collected for waveform amplitudes or EMG responses.[17]

TABLE 4 Summary of literature of EBSLN identification using visual and IONM-assisted identification

Study	Year	Nerves at risk	Surgical technique	Design	Visual identification (%)	IONM identification (%)
Barczynski et al.[9]	2012	420	Muscle splitting	RCT	34.3	83.8
Dionigi et al.[25]	2009	112	Video assisted	RCT	42	83.6
Lifante et al.[24]	2009	68	Minimally invasive	RCT	21	66
Darr et al.[16]	2014	29	Muscle splitting	PNR	NR	100
Loch-Wilkinson et al.[6]	2007	100	Strap division	PNR	86	87
Current study	2014	357	Strap division	PNR	85.7	97.2

EBSLN external branch of the superior laryngeal nerve, *IONM* intra-operative nerve monitoring, *PNR* prospective non-randomised study, *RCT* randomised controlled trial

The results of this series showed a higher frequency of type 2a nerves (54.6 %) compared to other series in which the frequencies of 17–31 % have been reported.[4,7,18] The possible reasons for this relate to the underlying thyroid pathology and differing conditions of identifying the nerve, with some studies being autopsy-based and others being operative-based.[7,18] Aina et al.,[1] using a similar technique of muscle division, but with a substantial number of patients with large goitres (39 % of patients had goitres >100 g), showed a similar rate of >50 % type 2a nerves.[1]

The use of IONM has been previously contentious due to a high rate of false-positive loss-of-signal events using the NIM. These events are largely due to technical and equipment issues and have been reported in up to 6 % of cases using older IONM equipment.[6,19,20] However, advances in technology appear to be addressing this issue, with only one case in 228 to be affected by technical issues in the present study. One such advance involves the use of improved endotracheal tubes with modified electrode arrays. The NIM TriVantage EMG Tube (Medtronic, Jacksonville, FL) used in this series has electrodes placed anteriorly above the vocal cords and posteriorly below the vocal cords to make the conduction more effective.[16] Endotracheal tube placement is critical for conduction and a close relationship with the anaesthetic team is essential for effective IONM with a standardised approach having been shown to be effective in reducing technical conduction problems.[21]

The use of IONM facilitates functional nerve testing during surgery pre- and post-dissection of the superior pole of the thyroid.[22,23] The presence of a strong and unambiguous cricothyroid twitch after stimulation of the EBSLN proximal to a sealed vessel is analogous to stimulating the vagus nerve post-thyroid lobe resection to confirm functional integrity of the recurrent laryngeal nerve.[24] This can be regarded as a form of intra-operative EMG and seems to us to be a valid alternative to postoperative cricothyroid EMG, which is an invasive test that lacks utility.[3]

One limitation of this study is the lack of results for formal and objective post-operative voice assessment. Although this is important, there are many factors that can alter voice in the absence of nerve injury; however, many of these are beyond the control of the surgeon such as postoperative scarring. The focus of this study was to examine the use of the NIM as a factor in preserving EBSLN function, which is a facet of postoperative voice function within the control of the surgeon. A further limitation of this series is the lack of an external control group without routine use of the NIM. The study is open to bias as the internal control was the surgeon applying routine operative techniques to identify the EBSLN. After confident visualisation of the EBSLN, the NIM was utilised as an adjunctive and objective tool to confirm the nerve presence and integrity. Failure to confidently identify the EBSLN then leads to use of the NIM as a discovery tool to elicit an unequivocal cricothyroid twitch. It could be argued that more extensive dissection may put the EBSLN at risk, however, in our series for the 10 patients where we could not find the nerve, no patient complained of loss of voice projection.

In conclusion, routine use of the NIM can accurately identify more than 97 % of EBSLNs and can improve identification over dissection of the EBSLN by 11.5 %. As the EBSLN is at risk during thyroid surgery, use of the NIM to confirm EBSLN function pre- and post-dissection of the upper thyroid pole can be regarded as an effective technique to preserve cricothyroid muscle function intra-operatively.

DISCLOSURE None.

REFERENCES

1. Aina EN, Hisham AN. External laryngeal nerve in thyroid surgery: recognition and surgical implications. *ANZ J Surg.* 2001;71(4):212–4.
2. Selvan B, Babu S, Paul MJ, Abraham D, Samuel P, Nair A. Mapping the compound muscle action potentials of cricothyroid muscle using electromyography in thyroid operations. *Ann Surg.* 2009;250(2):293–300.
3. Barczynski M, Randolph GW, Cernea CR, et al. External branch of the superior laryngeal nerve monitoring during thyroid and parathyroid surgery: international neural monitoring study group

standards guideline statement. *Laryngoscope.* 2013;123(Suppl 4):S1–14. doi:10.1002/lary.24301.
4. Cernea CR, Ferraz AR, Nishio S, Dutra A, Hojaij FC, Santos dos LR. Surgical anatomy of the external branch of the superior laryngeal nerve. *Head Neck.* 1992;14(5):380–3.
5. O'Neill CJ, Chang L-Y, Suliburk JW, Sidhu SB, Delbridge LW, Sywak MS. Sutureless thyroidectomy: surgical technique. *ANZ J Surg.* 2010;81(7–8):515–8. doi:10.1111/j.1445-2197.2010.05493.x.
6. Loch-Wilkinson TJ, Stalberg PLH, Sidhu SB, Sywak MS, Wilkinson JF, Delbridge LW. Nerve stimulation in thyroid surgery: is it really useful? *ANZ J Surg.* 2007;77:377–80. doi:10.1111/j.1445-2197.2007.04065.x.
7. Bellantone R, Boscherini M, Lombardi CP, et al. Is the identification of the external branch of the superior laryngeal nerve mandatory in thyroid operation? Results of a prospective randomized study. *Surgery.* 2001;130(6):1055–9. doi:10.1067/msy.2001.118375.
8. Jansson S, Tisell LE, Hagne I, Sanner E, Stenborg R, Svensson P. Partial superior laryngeal nerve (SLN) lesions before and after thyroid surgery. *World J Surg.* 1988;12(4):522–7.
9. Barczynski M, Konturek A, Stopa M, Honowska A, Nowak W. Randomized controlled trial of visualization versus neuromonitoring of the external branch of the superior laryngeal nerve during thyroidectomy. *World J Surg.* 2012;36(6):1340–7. doi:10.1007/s00268-012-1547-7.
10. Cernea CR, Nishio S, Hojaij FC. Identification of the external branch of the superior laryngeal nerve (EBSLN) in large goiters. *Am J Otolaryngol.* 1995;16(5):307–11.
11. Dionigi G. Energy based devices and recurrent laryngeal nerve injury: the need for safer instruments. *Langenbeck's Arch Surg*. 2008;394(3):579–80. doi:10.1007/s00423-008-0454-8.
12. Delbridge L. The "neglected" nerve in thyroid surgery: the case for routine identification of the external laryngeal nerve. *ANZ J Surg*. 2001;71(4):199–9. doi:10.1046/j.1440-1622.2001.02120.x.
13. Lennquist S, Cahlin C, Smeds S. The superior laryngeal nerve in thyroid surgery. *Surgery.* 1987;102(6):999–1008.
14. Friedman M, LoSavio P, Ibrahim H. Superior laryngeal nerve identification and preservation in thyroidectomy. *Arch Otolaryngol Head Neck Surg*. 2002;128(3):296–303.
15. Henry LR, Solomon NP, Howard R, et al. The functional impact on voice of sternothyroid muscle division during thyroidectomy. *Ann Surg Oncol.* 2008;15(7):2027–33. doi:10.1245/s10434-008-9936-8.
16. Darr EA, Tufano RP, Ozdemir S, Kamani D, Hurwitz S, Randolph G. Superior laryngeal nerve quantitative intraoperative monitoring is possible in all thyroid surgeries. *Laryngoscope*. 2014;124(4):1035–41. doi:10.1002/lary.24446.
17. Potenza AS, Phelan EA, Cernea CR, et al. Normative intraoperative electrophysiologic waveform analysis of superior laryngeal nerve external branch and recurrent laryngeal nerve in patients undergoing thyroid surgery. *World J Surg*. 2013;37(10):2336–42. doi:10.1007/s00268-013-2148-9.
18. Furlan JC, Cordeiro AC, Brandão LG. Study of some "intrinsic risk factors" that can enhance an iatrogenic injury of the external branch of the superior laryngeal nerve. *Otolaryngol Head Neck Surg*. 2003;128(3):396–400. doi:10.1067/mhn.2003.11.
19. Snyder SK, Hendricks JC. Intraoperative neurophysiology testing of the recurrent laryngeal nerve: plaudits and pitfalls. *Surgery*. 2005;138(6):1183–92.
20. Chan W-F, Lang BH-H, Lo CY. The role of intraoperative neuromonitoring of recurrent laryngeal nerve during thyroidectomy: A comparative study on 1000 nerves at risk. *Surgery*. 2006;140(6):866–73. doi:10.1016/j.surg.2006.07.017.
21. Dionigi G, Bacuzzi A, Boni L, Rovera F. What is the learning curve for intraoperative neuromonitoring in thyroid surgery? *Int J Surg*. 2008;6:S7–S12.
22. Snyder SK, Sigmond BR, Lairmore TC, Govednik-Horny CM, Janicek AK, Jupiter DC. The long-term impact of routine intraoperative nerve monitoring during thyroid and parathyroid surgery. *Surgery*. 2013;154(4):704–11. doi:10.1016/j.surg.2013.06.039.
23. Jonas J, Bähr R. Neuromonitoring of the external branch of the superior laryngeal nerve during thyroid surgery. *Am J Surg*. 2000;179(3):234–6.
24. Lifante J-C, McGill J, Murry T, Aviv JE, Inabnet WB III. A prospective, randomized trial of nerve monitoring of the external branch of the superior laryngeal nerve during thyroidectomy under local/regional anesthesia and IV sedation. *Surgery*. 2009;146(6):1167–73. doi:10.1016/j.surg.2009.09.023.
25. Dionigi G, Boni L, Rovera F, Bacuzzi A, Dionigi R. Neuromonitoring and video-assisted thyroidectomy: a prospective, randomized case-control evaluation. *Surg Endosc*. 2009;23(5):996–1003. doi:10.1007/s00464-008-0098-3.