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Neuromonitoring and video-assisted thyroidectomy: a prospective, randomized case-control evaluation

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Abstract

Introduction This study evaluates the role of intraoperative neuromonitoring (IONM) in video-assisted thyroidectomy (VAT) with emphasis given to the identification of recurrent laryngeal nerve (RLN) and external branch of superior laryngeal nerve (EBSLN).

Methods The study was based on a prospectively randomized series comprising 72 standard VAT gasless approaches. In the control group ($N = 36$), the laryngeal nerves were identified by 30° 5-mm endoscope magnification solely. The standard technique of the IONM group ($N = 36$) consisted of localizing and monitoring EBSLN, both vagus and RLNs, before and after thyroid resection to prove nerve integrity. Surgical outcomes were mean operative time, nerve representation, incision length, and morbidity.

Results All procedures were performed successfully. There were no instances of equipment malfunction or interference. No permanent complications occurred in either group. The incidences of temporary RLN injury were 2.7% (1 patient) and 8.3% (3 patients) in the IONM and control group, respectively. The EBSLN was identified better in the IONM group: 83.6% versus 42% ($p < 0.05$). In the IONM group, a negative electromyography (EMG) response indicated an altered function of RLN and stage thyroidectomy was scheduled.

Conclusions This is the first VAT series with a standardized IONM technique. The technical feasibility and safety of IONM in selected patients seem acceptable. Neuromonitoring during VAT is effective in providing identification and function of laryngeal nerves. IONM enables surgeons to feel more comfortable with their approach to VAT. A reduction of rates for postoperative complications could not be demonstrated in the present study. Larger series are needed for further evaluation.

Keywords Video-assisted thyroidectomy · Morbidity · Neuromonitoring · Recurrent laryngeal nerve · External branch of the superior laryngeal nerve · Stage thyroidectomy

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Injury to the recurrent laryngeal nerve (RLN) is the leading cause of vocal cord paralysis associated with hoarseness, impaired vocal register, dysphonia, dysphagia, and aspiration [1, 2].

Lesion of external branch of the superior laryngeal nerve (EBSLN) causes complete immobility of the cricothyroid muscle, impairing the production of high tones and altering the voice's frequency [3, 4].

Reports measured a 0.4–3.9% incidence of temporary RLN paralysis and a 0–3.6% incidence of permanent RLN lesions after thyroidectomy [5]. The rate of EBSLN injury reported in the literature is between 0.1% and 58% [6, 7].

Both RLN and EBSLN injuries are avoided with meticulous anatomic localization during surgical dissection [5, 6].

Intraoperative neuromonitoring (IONM) has been proposed as an adjunct to standard visual identification of the laryngeal nerves during open thyroid surgery. Technical advances currently allow accurate, noninvasive nerve monitoring [8]. Experience has shown that IONM allows the laryngeal nerves, both recurrent and superior, to be reliably identified and monitored during neck surgery [9]. Authors stated that IONM is an important adjunct in dissection and functional neural prognosis [10].

With numerous institutions beginning to perform more video-assisted thyroidectomies (VAT) [11], there is increased interest in new devices or techniques that may facilitate the surgical procedure itself, reducing morbidity and conversion rate compared with the conventional open technique.

The objective of this prospective randomized study is to assess the role of IONM as a means of identifying, monitoring, and assessing the function of the laryngeal nerves on the performance of VAT.

Patients and methods

Patients

VAT has been practiced in our center since 2004.

The study was conducted prospectively to determine if the outcomes of VAT performed with IONM (IONM group) were comparable to those with the conventional VAT technique without the use of neuromonitoring (control group).

Starting in 2007, 72 consecutive patients underwent the VAT approach in a single referral center specialized in endocrine surgery. We modified our VAT procedure, introducing the neuromonitoring procedure for localization of RLN and EBSLN in 36 of the 72 patients. Every patient eligible for enrollment was allotted to the corresponding group according to time of admission.

Selection criteria for both groups of patients are reported in Table 1. Exclusion criteria were history of cervical surgery (reoperation) including complete thyroidectomy, preoperative injury to laryngeal nerves, Graves' disease, laboratory and ultrasound signals of thyroiditis, advanced malignancy, associated parathyroid gland disease, intraoperative finding of tumor involvement of RLN, lymph node neck dissections, patients undergoing concomitant operations outside the neck, thyroidectomies performed in local anesthesia (Table 1). Based on the exclusion criteria, 11 patients were excluded from the study.

The main surgical outcome measures were patient demographics, weight of thyroid gland, type of operation performed (total thyroidectomy versus lobectomy), mean operative and hospitalization times, incision length, postoperative complications, and follow-up.

Patients were followed pre- and postoperatively in collaboration with the Division of Endocrinology of the University of Insubria, Varese, Italy.

For cancer patients, after surgery, patients were submitted to thyroid remnant ablation by radioactive iodine

Table 1 Study design: eligibility and exclusion criteria

Selection criteria
Dominant nodule size ≤35 mm
Thyroid US estimated volume ≤25 ml
"Low-risk" papillary thyroid cancer
RET gene carriers
Exclusion criteria
Large goiter (thyroid US estimated volume >25 ml)
Dominant nodule size >35 mm
Advanced cancer
Hyperthyroidism
Thyroiditis
Previous neck irradiation
Previous neck surgery
Preoperative injury to laryngeal nerves
Intraoperative finding of tumor involvement of RLN
Lymph node dissections
Associated parathyroid disease
Concomitant operations outside the neck
Local anesthesia
Obesity and stocky neck
Patients <18 years, or not able to provide informed consent

US, Ultrasound; RLN, recurrent laryngeal nerve

(^{131}I) and placed under thyroid stimulating hormone (TSH)-suppressive L-thyroxine therapy [12]. Preoperative diagnosis was based on ultrasound-guided fine-needle aspiration cytology and serum calcitonin measurement [12].

The following complications were analyzed: intra- and postoperative bleeding, seromas, wound infections, transient or definitive laryngeal nerve lesions, uni- or bilateral, permanent or transient hypocalcemia and parathyroid gland autotransplantation.

Hypocalcemia was checked by preoperative and daily inpatient serum calcemia, starting from the first postoperative day, and then at 7 and 14 days, and 1, 3, and 6 months after surgery. Intact parathyroid hormone (iPTH) levels were also determined postoperatively. Significant hypocalcaemia was defined as experiencing signs or symptoms of hypocalcaemia and/or having a serum calcium level that was ≤7.5 mg/dL (low end of normal for assay used is 8.5 mg/dL). Patients with postoperative hypocalcemia were discharged on a therapeutic regimen of oral calcium and cholecalciferol, which was continued until normalization of the calcium level.

Pre- and postoperative follow-up included for all patients direct laryngoscopy to check vocal cord mobility performed at 24–48 h before and within 2 weeks after the surgical procedure by an independent laryngologist. Any reduction in the movement of the cord was recorded as postoperative cord paralysis. For those patients with documented postoperative cord palsy, repeated examinations were performed periodically at 1, 2, 6, and 12 months after the operation until full recovery of vocal cord function had been confirmed usually after logopedy. Moreover, each patient completed the Voice Handicap Index postoperatively at 1 month after thyroidectomy [13].

Hypoparathyroidism and RLN palsy were defined as permanent when there was no evidence of recovery within 6 months of surgery.

Hospital discharge was proposed at 24–48 h after the operation if no signs of complications were present.

We tested the hypothesis that the use of IONM compared with no use of the device could shorten overall operative time and thus intubation. We routinely measured all the endoscopic procedures; in particular, we classified and calculated the anesthetist operative time (AOT) from patient entering the operating room to endotracheal tube correct placement confirmed by the correlation of electromyography (EMG) with respiratory activity. Care was taken to position the electrode accurately, since the adjustment of the head and neck after intubations can change the relative position of the tube and hence the electrode. Furthermore, the surgical operative time (SOT) was recorded by the circulating nurse as the time from skin incision to the application of the wound dressing.

As new instruments in endoscopic surgery are important variables for incision length, the mini-incision was routinely measured at the end of the endoscopic procedure and compared with the initial standard approach (i.e., 1.5 cm).

All procedures were performed by the senior author with 6 years of experience in endocrine surgery. The attending surgeon completed a perioperative data sheet that included procedure (IONM versus conventional VAT), number of applications of IONM per case, and intraoperative complications or equipment malfunction or interference.

This study was conducted in accordance with the principles of Declaration of Helsinki and good clinical practice guidelines. The study and procedure were explained to all patients preoperatively. The protocol and consent were approved by the local institutional review board and written informed consent was obtained from each patient in advance. Participants were assured anonymity. Included in the study were patients older than 18 years who were scheduled to undergo surgery and were able to provide informed consent.

Operative technique

Our current practice is to use IONM on all open thyroid operations since 2007.

The technique of IONM has been described previously [8, 14].

In the IONM group, succinylcholine (1 mg/kg) was used in the initial phase of general endotracheal anesthesia. No additional neuromuscular blocking agents were used following intubation. The Nerve Integrity Monitor (NIM-Response 2.0 System, Medtronic Xomed, Jacksonville, FL) was used for laryngeal-nerve monitoring.

In the IONM group, laryngeal nerves are located, mapped, and stimulated in the surgical field by the application of a sterile single-use pulse-generated monopolar stimulator probe (n.8225101, Medtronic Xomed). This stimulator has a 10-cm handle and 9-cm probe, with a flexible and adaptable 0.5-mm tip. The probe delivers an electric current that ranges from 0.5 to 2 mA. The probe is insulated to the tip to prevent current shunting. The identity of an intact nerve is confirmed through a series of audible acoustic signals generated by the machine.

Briefly, a standard VAT gasless approach to the thyroid gland was performed in both groups under general anesthesia [11]. The surgeon stands at the patient's right, the camera operator on the left, and an assistant with retractors at the patient's head. We routinely use a 30° 5-mm endoscope for both groups. Options for controlling hemostasis during VAT included the vessel sealing system (VSS) (LS1520-LigaSure™, Valley lab). When dividing thyroid blood vessels, the VSS is used with the power setting at level 2 to achieve balance between thermal spread and hemostasis. The upper pedicle, the middle vein, and inferior thyroid vessels are legated with the VSS. The VSS has been used to divide the thyroid tissue of the isthmus in hemithyroidectomies, to isolate the gland from the trachea. No additional dissection beyond the standard operative technique was performed or required in this series.

EBSLN identification

In both groups, the procedure starts with initial mobilization of the whole thyroid lobe with ligation of the middle thyroid vein.

The sternothyroid–laryngeal triangle is completely exposed with dedicated tiny spatulas and debrider–aspirator (Karl Storz, Endoskope™) [15]. The superior thyroid vessels and their branches are dissected meticulously and individually both cranially and caudally at their penetration point of the thyroid capsule.

In some situations (i.e., upper pole thyroid nodule), a partial incision of the sternothyroid muscle improved the access to the superior thyroid pedicle.

In the superior thyroid pole, the EBSLN may be closely related to the superior thyroid vessels. The superior thyroid artery is visualized but not sealed until the EBSLN is identified and exposed under optical magnification guidance (control group) or by coinciding both the 30° 5-mm endoscope visualization and neuromonitoring (IONM group). The positive identification of EBSLN is signaled by an audible signal and also is seen as a corresponding contraction of the cricothyroid muscle (intact function of EBSLN).

Superior thyroid vessels are individually divided by the VSS close to the thyroid gland to avoid injuring the EBSLN; gentle traction of the thyroid lobe caudally may help to preserve the integrity of the EBSLN.

RLN identification

After identification of the EBSLN and parathyroid glands, the inferior thyroid pole and RLN are routinely identified in all cases

In both groups, the whole cervical course of the RLN is traced and a safety margin of at least 2 mm is required between the VSS blade and the RLN. The inferior thyroid artery is visualized but not sealed until the nerve is exposed and isolated. The inferior thyroid artery is divided close to the thyroid gland to avoid injuring the nerve.

In the conventional group, the RLN is identified solely with the endoscope, giving a magnified view of the nerve.

In the IONM group, our standard technique is to stimulate both the vagus nerve and the RLN before and after thyroid resection [8]. In particular, we used the stimulator under optical guidance continually both prior (identification) and during (monitoring) the neural dissection of the tracheoesophageal groove.

At the end of the surgical procedure, with the optical magnification of the endoscope we ensure hemostasis and integrity of laryngeal nerves (conventional group). In the IONM group, the functional integrity of the nerves once again is confirmed by stimulation under optical visualization of the RLN and the vagus nerve [8]. The absence of a signal generated by the stimulator at any precise point along the nerve is regarded as a positive test. Nonpathologic and pathologic EMG responses were recorded.

If a parathyroid gland appeared to be damaged or hypovascularized, we reimplanted it in the sternocleidomastoid muscle. No thyroid bed drainage was necessary [11]. No patients received antibiotic prophylaxis [16].

Statistical analysis

Unless otherwise stated, all data for continuous variables are expressed as median and range. All patients' data were collected in a prospective manner with a dedicated electronic Microsoft Office Access database (Microsoft Corp, Redmond, WA). Data were collected daily until the day of discharge; then there was regular contact between the study coordinator and the participating specialist (endocrinologist, laryngologist, etc.) The database is part of our department's quality-improvement program. The use of this database for clinical research has been approved by our institutional review board. The two groups were formed using Bernoulli tables for randomization. Controls were selected on the basis of not having the outcome. The primary outcome measure was morbidity and mortality. In case of dichotomous variables, group differences were examined by χ^2 or Fisher exact tests as appropriate. Statistical analysis was computed with SPSS, release 15.0 for Windows (SPSS Inc., Chicago, IL). The level of significance was set at p less than 0.05. All efforts were made to avoid sources of bias such as the loss of individuals to follow-up during the study.

Results

The study represents the result of the collaboration at the University Hospital of Varese between the Department of Surgical Sciences, the Division of Endocrinology, Anesthesiology, and Neurology.

Both the unmonitored and monitored group consisted of 36 patients each.

The control group included 30 women and 6 men with a mean age of 39.8 years (range 19–77 years). The IONM group comprised 32 women and 4 men with a mean age of 41 years (range 25–68 years).

Complete follow-up was available for all patients.

There were no statistical differences between the two groups in terms of distribution of epidemiological characteristics, thyroid pathology, types of operations, the proportion of bilateral procedures, and mean weight of the thyroid ($p > 0.05$) (Table 2).

The overall mean thyroid volume estimated by preoperative ultrasound (US) was 16 ml (range 11–25 ml). Mean size of dominant nodule was 2.1 cm (range 1.2–3.5 cm). The treated pathologies were mainly follicular tumor and nodular goiter (Table 3).

There were 55% total thyroidectomies ($n = 40$) and 45% hemithyroidectomies ($N = 32$), providing 224 nerves at risk for examination. In detail, the number of nerves that were at risk was 110 and 114 in the IONM and control groups, respectively ($p < 0.05$).

The two groups had similar operating times ($p > 0.05$), both AOT and SOT. In detail, in the IONM group, overall mean operative time was 49.5 min (range 39–120 min) for lobectomy and 97.6 min (range 59–130 min) for total thyroidectomy. In the control group, mean operative time was 46.5 min (range 32–110 min) for lobectomy and 95.0 min (range 58–135 min) for total thyroidectomy.

At the end of the procedure, the mean length of the incision was not significantly increased in either the IONM group (+0.3 cm) or the control group (+0.2 cm) ($p > 0.05$).

It is our routine practice for patients to remain in the hospital overnight following VAT. Mean hospital stay was similar in the standard VAT and IONM groups. In the

Table 2 Preoperative characteristics and operative parameters in 72 patients undergoing VAT

	Control group ($N = 36$)	IONM group ($N = 36$)	p
Age (years)	39.8 (19–77)	41 (25–68)	NS
Women (N)	30	32	NS
Men (N)	6	4	NS
Thyroid volume (ml)[a]	16 (11–26)	17 (12–23)	NS
Dominant nodule diameter (cm)	2.2 (0.7–3.5)	1.9 (1–3.3)	NS
Lobectomy ($N = 32$)	15	17	NS
Total thyroidectomy ($N = 40$)	21	19	NS
Nerves at risk			
Total	114	110	NS
RLN	57	55	
EBSLN	57	55	

IONM, intraoperative neuromonitoring; RLN, recurrent laryngeal nerve; EBSLN, external branch of superior laryngeal nerve; NS, not significant. [a] Estimated by preoperative ultrasonography; Data are numbers or mean with ranges in parentheses

Table 3 Preoperative diagnosis

	Control group ($N = 36$) N (%)	IONM group ($N = 36$) N (%)	p
Follicular tumor	22 (61)	18 (50)	NS
Nodular goiter	11 (31)	17 (47)	NS
Hurtle	3 (8)	1 (3)	NS

IONM, intraoperative neuromonitoring; NS, not significant

IONM group, 27 of 36 patients (76%) experienced an overnight hospital stay (<24 h) compared with 25 of 36 patients (69%) in the control group ($p > 0.05$).

All endoscopic procedures were performed successfully; no cases required conversion to open surgery, none involved significant intraoperative complications, and there were no instances of equipment malfunction or interference with the other endoscopic instruments of VAT.

In the IONM group, the nerve stimulator was applied a mean of 14 times (range 8–19 times) per case for a total of 612 applications.

No mortality was observed.

Overall morbidity was as high as 13.8% ($N = 5$) in the IONM group and 25% ($N = 9$) in the control group, and in most cases included transient complications (Table 4) ($p > 0.05$).

No patient required reoperation. There were no other perioperative incidents; in particular, no hemorrhagic complications or cervical hematoma was observed. One patient in the control group experienced a wound seroma. No patients reported wound infection.

No bilateral vocal cord paresis or paralysis occurred. There were no cases of permanent hypocalcemia or RLN/EBSLN paralysis in either group. The incidence of temporary hypoparathyroidism in the IONM group was 11% (4/36) versus 13.8% (5/36) in the conventional group ($p > 0.05$). One patient of the IONM group was readmitted with a diagnosis of symptomatic hypocalcemia 3 days after discharge.

In the control group, the RLN was identified in all cases (100%). In the IONM group, the vagus nerve and the RLN were correctly localized and monitored in all cases (100%).

The EBSLN was identified in 42% of cases (24/57) in the control group. In the IONM group, the EBSLN was

Table 4 Post-operative morbidity

	Control group ($N = 36$) N (%)	IONM group ($N = 36$) N (%)	p
Wound complication	1 (seroma) (2.7)	0	NS
Permanent hypoparathyroidism	0	0	
Permanent RLN injury	0	0	
Temporary hypocalcaemia	5 (13.8)	4 (11)	NS
Temporary RLN injury	3 (8.3)	1 (2.7)[a]	NS
TOTAL	9 (25%)	5 (13.8%)	NS

IONM, intraoperative neuromonitoring; RLN, recurrent laryngeal nerve; NS, not significant

[a] The injured left RLN was confirmed through a negative EMG signal intraoperatively. This patient was scheduled for total thyroidectomy. The procedure was stopped after the first left lobectomy, to avoid the potential for bilateral vocal cord paralysis. Direct laryngoscopy at 48 h postoperatively confirmed a reduction in the movement of the left vocal cord. A completion right VAT was performed at 3 months postoperatively when full recovery of left vocal cord function was achieved after logopedy

Table 5 Laryngeal nerves localization (224 nerves at risk)

	Control group ($N = 114$) N (%)	IONM group ($N = 110$) N (%)	p
RLN	57/57 (100%)	55/55 (100%)	NS
EBSLN	24/57 (42%)	46/55 (83.6%)	$p < 0.05$

IONM, intraoperative neuromonitoring; RLN, recurrent laryngeal nerve; EBSLN, external branch of superior laryngeal nerve; NS, not significant

localized and monitored in more cases: 83.6% (46/55) of cases ($p < 0.05$; Table 5).

Overall EBSLN course ($n = 70$) was medial to superior thyroid artery branches in 57 cases (81.4%) and crossed anteriorly such branches in 13 cases (18.6%).

The incidence of temporary RLN injury in the IONM group was 2.7% (1 patient) versus 8.3% (3 patients) in the control group. Because of insufficient numbers of RLN palsies (1 patient versus 3 patients) a statistically significant result was not achieved.

In the only patient in the IONM group with RLN injury, the identity of the injured nerve was confirmed through a negative signal generated by the machine by stimulating both the left RLN and vagus nerve (post thyroid resection stimulation). By mapping the whole cervical course of the RLN proximally and distally, we found that the left RLN was injured in the last 2 cm of its course: endoscopically it was hard to judge the nerve injury (probably a stretch or blunt injury). This patient was scheduled for a total thyroidectomy for a bilateral diffuse multinodular goiter. The procedure was stopped after the first left lobectomy to avoid the potential for bilateral vocal cord paralysis. Laryngoscopy performed at 48 h postoperatively confirmed a reduction in the movement of the left vocal cord. A repeated examination was performed at 1 and 2 months after the operation until full recovery of vocal cord function was confirmed after logopedy. The patient underwent completion right VAT after 3 months from first operation without complications.

Discussion

Evidence-based data have emphasized the benefits of VAT [17–20]. Thus, any modifications to established operative technique for VAT should result in similar, improved patient outcomes with lower rates of complications.

Nerve or laryngeal palpation (tactile sensation) or the use of magnifying glasses as intraoperative techniques for identifying EBSLN and RLN during VAT is not feasible for the small incision (i.e., 1.5 cm). VAT requires the surgeon to rely more fully on visual cues from the monitor. Certainly, the image magnification by the newly available high-definition endoscopes facilitates the identification of laryngeal nerves and parathyroid glands, providing visual discrimination among different tissues and depths [21–23].

The availability of a noninvasive IONM led us to try this tool for VAT. We designed a study employing the nerve-integrity monitor in VAT. We hypothesize that monitoring the RLN and EBSLN in this fashion will prevent and/or decrease the risk of iatrogenic injury and additional risk to the patient. Our goal is to combine the potential advantages of minimally invasive access with IONM.

Our initial clinical results demonstrate IONM to be feasible, easy, safe, and effective in VAT.

To our knowledge, this is the first prospective randomized series of patients undergoing VAT with the use of IONM. Terris et al. demonstrated in a prospective analysis that IONM serves as an adjunct to the visual identification of nerves [24]. The study was nonrandomized and included all minimal-access thyroid surgery procedures performed through an incision of less than 6 cm, both endoscopic and nonendoscopic as well as reoperative cases [24].

The power of our study may be the research protocol characterized by a meticulous selection of patients undergoing VAT, which is homogeneous in both groups. Moreover, we first propose a standardized technique for identifying and assessing the function (*prognosis*) of laryngeal nerves with IONM during VAT: the RLN and vagus nerve are both stimulated before and after thyroid resection to prove RLN integrity. This is in concordance with Timmermann et al. and Dralle et al. [8, 14]. In the IONM group, the vagus nerve was stimulated directly by dissecting the carotid shift or in some cases by simply applying the stimulator on the carotid shift without dissection (usually in patients with low fat in the neck). We found that this technique did not increase morbidity, surgical incision length, or operative time.

The small operative space and the possible problems linked to the specific endoscopic instrumentation in terms of size and design to operate on the neck did not appear to constitute important obstacles to the utilization of this technique. IONM is atraumatic; in fact, there were no intraoperative complications or instances of equipment malfunction or interferences. There were no conversions to the traditional open approach or wound complications. The flexible tip of the monopolar stimulating probe allowed good access to neural structures in areas outside the surgeon's field of view.

The introduction of IONM in VAT involves several other considerations.

The first observation is relative to the other minimally invasive techniques described in the literature, especially the fully endoscopic extracervical approaches such as axillary or breast access [25, 26]. Technically these may need a longer stimulator to perform IONM due to the greater distance to the neck from trocar insertion in the axilla or nipple area.

VAT surgery has, more than any other minimally invasive procedure, created extreme controversy and debate, particularly within the establishment [27]. On reflection, this is not surprising given that few specialist surgeons are trained to do it. With time, continuous technical refinements, learning curve, and experience, more patients could become candidates for VAT [28–30]. We believe that IONM enables surgeons to feel more comfortable and confident with their initial approach to the VAT procedures. The stimulator itself is useful to indicate the correct plane of dissection, giving constant information during operation of laryngeal nerve function and probably reducing the conversion rate to the conventional open technique. Using the neuromonitoring procedure, we were able to exclude the presence of EBSLN and RLN in each step of dissection and ligation. A negative EMG response indicated a nonnerve structure or altered function of the RLN. IONM provides important prognostic information regarding ipsilateral vocal cord function at the completion of the initial side of the VAT surgery. In our experience, IONM allowed the surgeon to stage contralateral surgery if RLN damage is diagnosed, thereby avoiding the potential for bilateral vocal cord paralysis. Several studies have shown how poor the surgeon is at judging RLN injury intraoperatively. RLN injury during thyroidectomy may be caused by traction, pressure, crush, electrical injury, ligature, ischemia, or suction injury without transaction [31]. In these cases the injured nerve may, to the surgeon's eye and video-endoscope, appear intact [31, 32]. Patlow et al. found that in only one of ten cases of RLN injury were surgeons aware of the injury [32].

IONM has been claimed in some studies to reduce rates of nerve injury, whereas other studies have found no benefit. Authors reported that the incidence of RLN lesions in benign, malignant, and recurrent thyroid disease was not decreased by the use of intraoperative neuromonitoring [33, 34]. Hermann et al. concluded, in a prospective study, that neuromonitoring is useful for identifying the recurrent laryngeal nerve, in particular if the anatomic situation is complicated by prior surgery or large tissue masses (not included in this study) [35]. Numerous studies have shown that only routine exposure of the RLN is associated with very low rates of injury in high-volume centers (less than 0.3%) [5].

Many limitations exist in the interpretation of the results of this study, including the limited number of patients and the selection of the indications. For example, a significant reduction of the rates for postoperative complications could not be demonstrated in the present study. In order to compare the use of standard VAT and IONM, a multicenter trial with large numbers and well-defined groups is needed. Eisele noted that, to show a reduction in RLN paralysis rates from 2% to 1% per nerves at risk, a study group of approximately 1,000 patients would be necessary [36]. In our center, most thyroidectomies are still performed for large goiters or cancers. VAT procedures are limited to a minority of patients (about 5% of thyroidectomies), mainly "diagnostic" surgery for undetermined nodules in small goiters and follicular tumors. Thus, at present, it is difficult to demonstrate a statistical benefit of IONM during VAT. This is the weak point of our preliminary research.

We agree with Terris et al. that IONM is complimentary to video-endoscope magnification [24]. We have demonstrated that the IONM method improved identification of the EBSLN in a selective consecutive series of patients. The endoscope allows identification also of the EBSLN, giving a magnified view of the EBSLN during selective ligation of the upper pedicle [23]. The surgical importance of this nerve relates to its proximity to the superior thyroid vessels [3]. In our study, the EBSLN was better identified in the IONM group than in the control group (83.6% versus 42%) ($p < 0.05$). Berti et al. reported a 65% of rate of localization of EBSLN in VAT without IONM [23]. In the remaining cases not identified, the EBSLN was probably located within the fibers of the inferior pharyngeal constrictor muscle [37].

IONM during thyroidectomy may be easily organized in centers of endocrine (thyroid) surgery. However, most patients with thyroid problems are still treated in smaller surgical units. Therefore, IONM may be a logistical problem. There are several criticisms of the use of IONM, focused mainly on the cost: the device is expensive. We did not consider its cost in this research.

Perhaps the monitoring of nerves during surgical procedures potentially reduces the medico-legal liability for surgeons [38].

We believe that IONM affects the *quality* of our VAT procedures [39]. Standardization of the technique, specific experience, and training with this device is essential for optimal use. Further evaluation is needed to determine the indications of this procedure in patients undergoing VAT. We do not however support technology over sound common sense, and recognize the need to convert the planned procedure if required.

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Authors' contributions GD: acquisition of data; FR, LB: study conception and design; GD: analysis and interpretation of data; LB, BA: drafting of manuscript; RD: Critical revision and supervision.

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