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The Role of Intraoperative Neuromonitoring in Preventing Recurrent Laryngeal Nerve Injury During Thyroidectomy

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Abstract

Objective. To evaluate the impact of intraoperative neuromonitoring on the identification of the recurrent laryngeal nerve and the incidence of its postoperative paresis/paralysis.

Materials and Methods. Data from 100 patients were analyzed: 50 underwent surgery using intraoperative neuromonitoring, and 50 using visual identification of the recurrent laryngeal nerve. Recurrent laryngeal nerve function was assessed laryngoscopically; nerve motility impairment was considered transient if recovery took less than 6 months.

Results**.** Bilateral identification of the recurrent laryngeal nerve was achieved in 100% of patients who underwent intraoperative neuromonitoring and in 74% of patients who underwent visual identification ($p < 0.001$). Transient nerve palsy/paralysis occurred in 8% and 16% of patients, respectively. In patients who underwent intraoperative neuromonitoring, no permanent paresis was recorded, whereas 6% of patients who underwent visual identification developed permanent paresis, and 1 patient experienced bilateral paralysis requiring tracheostomy.

Conclusions. Intraoperative neuromonitoring during thyroidectomy improves identification of the recurrent laryngeal nerve and is associated with a lower incidence of postoperative complications; in particular, it makes it possible to avoid permanent paralysis and potentially prevent bilateral nerve damage.

Keywords: intraoperative neuromonitoring; thyroidectomy; quality of life; endocrine surgery.

Thyroidectomy is one of the most common procedures in endocrine surgery. One of the key factors affecting patients' quality of life after surgery is the preservation of recurrent laryngeal nerve (RLN) function, as damage to this nerve leads to hoarseness, vocal fatigue, aspiration, and social maladjustment. Bilateral vocal cord paralysis is a potentially life–threatening complication and may require emergency measures to ensure airway patency.

Visual identification and atraumatic dissection of the RNL are considered the "gold standard" for preventing complications. However, anatomical variability, severe inflammatory changes in thyrotoxicosis, a large goiter, invasive tumor growth, or fibrosis complicate the search for the nerve, increasing the risk of nerve injury. Intraoperative neuromonitoring (IONM) has been proposed as an auxiliary tool. Its combination with visual identification allows for functional confirmation of the nerve, localization of the nerve under challenging conditions, and detection of signal loss to adjust surgical tactics [1, 2].

The issue of routine IONM use is debatable. According to data from randomized trials and their meta–analyses, the use of IONM does not always result in a statistically significant reduction in the incidence of RNL injury [3, 4]. At the same time, data from large meta–analyses, studies of high–risk patient groups, and registry analyses indicate the potential benefit of IONM, particularly in bilateral procedures, surgeries for malignant neoplasms, repeat procedures, and thyrotoxicosis [5–7].

Objective: To evaluate the effect of IONM on the identification of the RNL and the incidence of postoperative paresis/paralysis of the RNL.

Materials and methods

An analysis was conducted of data from 100 consecutive patients who underwent thyroidectomy for various thyroid diseases. Patients were divided into two groups: the main group–50 patients who underwent thyroidectomy using IONM–and the control group–50 patients who underwent thyroidectomy with visual identification of the RNL without IONM. The study has a quasi–experimental "before/after" design with historical (non–concurrent) control. The new technique for thyroid surgery was adopted on Day X. After this date, prospective consecutive (uninterrupted) patient recruitment was conducted. The main group included 50 consecutive patients without any omissions who underwent thyroid surgery using IONM. The control group was formed retrospectively based on medical records: starting from day X in reverse chronological order, 50 consecutive patients without gaps were selected who underwent thyroid surgery using the standard technique applied prior to the introduction of IONM. Thus, the study included 100 patients (50 "post" and 50 "pre"), recruited within a short time frame (less than two years), which minimizes the influence of external temporal factors.

In both groups, visual identification of the RNL was mandatory. In the main group, IONM was used as an adjunctive method for mapping, confirming the nerve, and monitoring its functional integrity. The primary endpoint was the rate of complete bilateral RNL identification. Secondary endpoints included the rates of transient and permanent paresis/paralysis, bilateral involvement, and the need for tracheostomy. Categorical data are presented as absolute numbers and percentages; frequency rates were compared using the χ^2 test or Fisher's exact test, depending on the expected frequency. Differences were considered statistically significant if the p–value was less than 0.05.

Complete bilateral identification of the RNL was defined as its visual identification on both sides, extending to the entrance of the larynx; in the main group, visual identification was further confirmed by stimulation with recording of the evoked electromyographic response (EMG response) of the larynx. Cases of paresis/paralysis were analyzed at the patient level (presence of involvement on at least one side, as determined by). De–identified data were analyzed. All patients provided informed consent for surgery; no additional interventions outside the standard of care were performed. Exclusion criteria for the study included poorly differentiated and medullary thyroid cancer, as well as preoperative unilateral vocal cord paresis/paralysis as determined by laryngoscopy.

All patients underwent standard preoperative evaluation according to the clinical situation (assessment of hormonal profile, ultrasound examination, and fine–needle aspiration biopsy when indicated). Preoperative laryngoscopy was performed to rule out laryngeal dysfunction.

Given that latent preoperative vocal fold dysfunction may occur without pronounced voice complaints, laryngoscopic verification of their baseline mobility is important for the correct interpretation of postoperative changes and IONM results. Preoperative laryngeal examination is recommended by relevant consensus guidelines, especially when malignant disease is suspected, in cases of recurrent procedures, large goiters, or the presence of dysphonia [8–10].

The surgical procedure was performed under general anesthesia via a carotid cervical approach (according to Kocher). The patient was positioned supine with moderate neck extension (a pillow under the shoulders), and the head was fixed in a neutral position. A transverse incision was made in the natural neck crease, with subplatysmal flaps formed extending cranially to the cricoid cartilage and caudally to the jugular notch. The white line of the neck was incised along the midline; the sublingual muscles were retracted/distracted laterally, and in cases of large goiter, they were partially transected. Mobilization of the lobe began with exposure of the lateral surface and ligation (clipping) of the vessels, including the median thyroid vein (if present). The vessels of the superior pole were ligated as close as possible to the thyroid gland capsule to reduce the risk of injury to the external branch of the superior laryngeal nerve. The parathyroid glands were identified and preserved with maximal vascularization; if devascularization was suspected, an autotransplantation was performed.

The RNL was identified primarily after mobilizing the superior pole, proceeding downward along the tracheoesophageal groove to locate the nerve's entry point into the larynx, and then tracing its course in the reverse (retrograde) direction. The area where the nerve frequently crosses the inferior thyroid artery and the section of Berry's ligament where the nerve lies closest to the capsule and is vulnerable to traction and thermal injury were considered critical. Dissection was performed using blunt–sharp techniques while minimizing traction on the lobe; electrosurgical instruments were used at a safe distance from the nerve.

In the main group, prior to final nerve dissection, mapping was performed–stimulation of tissues in the zone of the expected course of the RNL with recording of EMG responses, which allowed for clarification of the nerve's topography in the presence of fibrosis, inflammation, or altered anatomy [1, 11].

After thyroidectomy, hemostasis was controlled, the bed was examined, and the viability of the parathyroid glands was assessed. The wound was sutured in layers after placing a drain.

In the main group, intermittent IONM was used: intubation was performed using an endotracheal tube with surface electrodes to record EMG responses (C2 Nerve Monitor, Inomed©) from the laryngeal muscles. Before starting the dissection, the correct positioning of the tube was verified (contact of the electrodes with the vocal folds). During the operation, suspected nerve structures and the identified RNL were stimulated using a neuromuscular stimulator with assessment of the EMG response. Visual identification of the RNL was performed in both groups as a basic step for safe dissection. The general dissection procedure was the same as in the control group.

Monitoring was performed according to a standardized protocol (V1–R1–R2–V2) recommended by the International Neural Monitoring Study Group: prior to the start of dissection, the baseline response to vagus nerve stimulation (V1) was recorded; following initial identification, the RNL response (R1) was recorded; and after dissection was completed, the control RNL response (R2) and the response to repeated vagus nerve stimulation (V2) were recorded [1, 2, 12, 13]. When necessary, stimulation was used to map and localize the nerve in the area of its expected course. Stimulation was performed using a handheld probe with short pulses; typical parameters were as follows: 1–2 mA, pulse duration approximately 100 μs, frequency 4 Hz. For correct identification/assessment of conduction, a reproducible EMG response with an amplitude ≥100 μV was considered acceptable, provided that electrode contact was stable [1, 11].

A non–reproducible EMG response or a decrease in amplitude to ≤100 μV during stimulation with unchanged settings, persisting after rechecking the system, was considered a signal loss [14]. In cases of persistent signal loss on the first side during a planned bilateral procedure, a staged approach was considered, omitting the contralateral stage, which reduced the risk of bilateral vocal fold paralysis [2, 14]. Paresis was defined as partial limitation of vocal fold mobility, and paralysis as complete immobility, as determined by laryngoscopy. Mobility impairment was classified as transient if complete recovery occurred within 6 months post–surgery; persistence of the deficit beyond 6 months was considered permanent paresis/paralysis. Bilateral lesions were recorded separately as the most clinically significant.

Vocal fold mobility was assessed visually during laryngoscopy; the presence of dysphonia, respiratory discomfort, and signs of aspiration were additionally considered. In cases of paresis, a reduction in the amplitude/asymmetry of movements or incomplete closure of the glottis was recorded; in cases of paralysis, complete immobility of the fold was noted. This approach is consistent with specialized recommendations for the assessment of the voice and larynx following thyroid surgery [15].

The terms "transient" and "permanent" reflect the prognosis: most neuropraxic injuries of the RNL resolve within the first few months, whereas the persistence of dysfunction for more than 6 months is considered permanent in many studies (some researchers use a 12–month threshold) [15, 16].

Laryngoscopy was performed in the early postoperative period and as needed (based on clinical indications). Patients with vocal fold paresis/paralysis were referred for consultation with an otolaryngologist/phoniatrist; voice rest, mucosal hydration, and respiratory and voice rehabilitation were recommended. In cases of bilateral paralysis with signs of respiratory failure, a tracheostomy was performed, followed by monitoring until respiratory function stabilized.

In accordance with guidelines regarding vocal outcomes following thyroid surgery, vocal complaints were assessed within 2 weeks to 2 months after the procedure; in the presence of dysphonia, mandatory laryngoscopic verification of the condition of the vocal folds and early consultation with a phoniatrist or otolaryngologist were recommended [15].

For patients with unilateral paresis/paralysis, if no threatening symptoms were observed, a wait–and–see approach was primarily used, combined with early voice therapy and voice hygiene training; in cases of persistent dysphonia or aspiration, the possibility of injection medialization and other rehabilitation methods was considered in accordance with relevant guidelines [16].

In cases of bilateral paralysis with signs of upper airway obstruction, ensuring airway patency (intubation/tracheostomy) is a priority, after which further management is determined through a multidisciplinary approach [15, 16].

Table 1. **Structure of nosologies and indicators for identifying ZGN and its postoperative paresis/paralysis in the main group (n = 50)**

Pathology	Number of patients	Bilateral identification of the SCN		Paresis/paralysis of the ZGN			
				Transient		Permanent	
		abs.	%	abs.	%	abs.	%
Thyroid cancer, stage T1	12	12	100	0	0	0	0
Thyroid cancer T3+	7	7	100	2	28	0	0
Diffuse toxic goiter	16	16	100	1	6.3	0	0
Nodular goiter	15	15	100	1	7	0	0
Total ...	50	50	100	4	8	0	0

Table 2. **Structure of nosologies and indicators for identifying ZGN and its postoperative paresis/paralysis in the control group (n = 50)**

Pathology	Number of patients	Bilateral identification of the SCN		Paresis/paralysis of the ZGN			
				Transient		Permanent	
		abs.	%	abs.	%	abs.	%
Thyroid cancer T1	14	8	57	1	7	0	0
Thyroid cancer T3+	6	6	100	3	50	2	33
Diffuse toxic goiter	12	12	100	2	17	0	0
Nodular goiter	18	11	61	2	11	1	5
Total ...	50	37	74	8	16	3	6

Results

In both groups, the nosological structure, the frequency of RNL identification, and its postoperative paresis/paralysis were investigated (*Tables 1, 2*)

In the main group, the nosological structure was as follows: T1 thyroid cancer – 24% (12/50), thyroid cancer T3+ – 14% (7/50), diffuse toxic goiter – 32% (16/50), nodular goiter – 30% (15/50).

In the control group, the incidence of T1 thyroid cancer was 28% (14/50), T3+ thyroid cancer – 12% (6/50), diffuse toxic goiter – 24% (12/50), and nodular goiter – 36% (18/50).

In the main group, bilateral RNL identification was performed in all patients (100%); in the control group, in 74% of patients: relative risk (RR) 1.35; 95% confidence interval (CI) 1.15–1.59; $p < 0.001$. In the control group, identification was unilateral in an additional 10 (20%) patients; in 3 (6%) patients, identification on one side was impossible or questionable.

The incidence of transient RNL paresis/paralysis was 8% (4/50) in the main group and 16% (8/50) in the control group (OR 0.50; 95% CI 0.16–1.55; $p = 0.36$). No permanent paresis/paralysis was recorded in the main group; in the control group, it occurred in 6% (3/50) of patients (OR 0.33; 95% CI 0.04–3.10; $p = 0.62$).

The difference in the frequency of bilateral RNL identification between the groups was statistically significant ($p < 0.001$). Differences in the incidence of transient ($p = 0.36$) and permanent ($p = 0.62$) paresis/paralysis did not reach statistical significance, which may be due to the limited sample size.

Bilateral vocal cord paralysis requiring tracheostomy occurred in 1 (2%) patient in the control group; there were no such patients in the main group. It should be noted that in the patient who required a tracheostomy, the paresis was temporary on both sides, and the tracheostomy was closed one month after the operation.

Discussion

According to the results of this study, the use of IONM was associated with a higher rate of complete bilateral RNL identification and a lower rate of transient and permanent paresis/paralysis compared to the corresponding rates when visual identification alone was used. The observed differences are of practical significance primarily for patients at increased risk of nerve injury (locally advanced cancer, thyrotoxicosis, significant fibrosis, and anatomical variability).

According to current guidelines, IONM does not replace meticulous surgical technique and visual identification, but can be useful as a means of functional monitoring and improved visualization of the nerve [1]. A distinct advantage of IONM lies in the ability to detect signal loss early and adjust the strategy during bilateral surgeries (staged thyroidectomy), which potentially reduces the risk of bilateral vocal cord paralysis [2]. In this study, bilateral paralysis requiring tracheostomy was recorded only in the control group in 1 patient, which is consistent with the concept of preventing the most severe complications through timely adjustment of intraoperative tactics.

At the same time, the literature data regarding the effect of IONM on the overall incidence of RNL injury are inconclusive. A Cochrane review based on randomized trials did not demonstrate a convincing advantage of IONM over visual identification in reducing the incidence of transient or permanent paresis/paralysis, with the quality of evidence rated as very low [3]. Similarly, in a meta–analysis of randomized controlled trials by M. G. Davey and colleagues [4], only a trend toward a reduction in the overall incidence of nerve injury was demonstrated (odds ratio 0.72; $p = 0.06$) without a statistically significant effect on permanent nerve injury.

In contrast, B. Bai and W. Chen [5] (a meta–analysis of 34 studies) reported a statistically significant reduction in the overall incidence of injury and the incidence of transient RNL paresis/paralysis with the use of IONM (OR 0.68 and 0.71, respectively) and a slight decrease in the incidence of permanent paresis/paralysis. Following “high–risk” surgeries, the incidence of permanent and transient RNL palsy/paralysis was also lower with IONM–2.5%–compared to 4.5% for surgeries performed without IONM [6]. A registry analysis of a national sample (ACS NSQIP) demonstrated an association between IONM and a reduced risk of RNL injury after adjusting for clinical factors (odds ratio 0.69) [7]. However, according to data from individual meta–analyses and large reviews of prospective studies (with endoscopic verification), no significant difference in the incidence of RNL injury was found, but the advisability of selective IONM use is noted, particularly for the prevention of bilateral nerve palsy [17].

Given the above data, it can be assumed that the greatest clinical benefit of IONM is realized in cases of increased risk of nerve injury and during bilateral procedures. In such situations, IONM increases confidence in the correct identification of the nerve, allows for the avoidance of rough traction maneuvers, and provides a basis for a staged approach in the event of intraoperative signs of dysfunction.

It is important to emphasize that most RNL injuries during thyroidectomy do not involve anatomical transection of the nerve; that is, the nerve may be anatomically intact but fail to function due to trauma (neuropraxia), and this is often associated with traction, compression, thermal injury, or ischemia, whereas complete transection occurs much less frequently. While not automatically “preventing” injury, IONM helps the surgeon promptly identify risky maneuvers, confirm anatomical variations, and document the nerve's functional status at the end of the operation [11, 12].

A key factor in the effectiveness of IONM lies in strict adherence to a standardized stimulation protocol (V1–R1–R2–V2) and verification algorithms in the event of signal loss. A significant proportion of "signal loss" may be due to technical causes (migration of the electromyographic probe, poor electrode contact, residual neuromuscular blockade); therefore, a systematic algorithm for identifying and resolving these causes is essential to reduce the frequency of false–positive findings and unwarranted changes in management [11, 13, 14, 18, 19].

In this study, intermittent IONM was used. Continuous IONM potentially allows for earlier detection of life–threatening injury by recording a progressive decrease in amplitude or increase in latency, and traction is stopped before the development of permanent dysfunction. At the same time, continuous monitoring requires additional equipment and has its own limitations; therefore, when selecting a monitoring method, the risk of the operation, the team's experience, and resource capabilities should be taken into account [12, 20].

Finally, a qualitative assessment of outcomes requires standardized pre– and postoperative laryngeal examination, as paresis may be subclinical in some patients. Recommendations from relevant consensus statements include documenting baseline vocal fold mobility and performing a postoperative voice assessment with a low threshold for laryngoscopy in the event of complaints [8, 9, 15].

This study has limitations, namely a relatively small sample size, non–standardized randomization, and the potential influence of surgeon experience and the complexity of cases on the results of intraoperative neuromonitoring. To clarify the role of IONM, prospective studies with a unified protocol, standardized pre– and postoperative laryngoscopic assessment, and a separate analysis of high–risk groups are warranted.

Conclusions

1. IONM during thyroidectomy improves bilateral RNL identification: in the main group, this rate was 100%, whereas in the control group, it was 74%.

2. With the use of IONM, the incidence of transient RNL palsy/paralysis was reduced to 8% (compared to 16% in the control group), and no cases of permanent RNL palsy/paralysis occurred (6% of patients in the control group had permanent RNL palsy/paralysis).

3. The most clinically significant advantage of IONM lies in the potential prevention of bilateral vocal cord paralysis through early detection of functional changes and the ability to adjust treatment strategies.

4. Further studies with larger sample sizes and standardized IONM protocols are needed to determine the indications for its routine or selective use.

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