

# The value of intraoperative nerve monitoring against recurrent laryngeal nerve injury in thyroid reoperations

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## Abstract

Reoperative thyroidectomy is challenging for surgeons because of the higher incidence of recurrent laryngeal nerve (RLN) palsy. RLN identification is the gold standard during thyroidectomy; however, it is sometimes difficult to perform thyroid reoperations. In recent years, intraoperative nerve monitoring (IONM) has gained increased acceptance, and the use of IONM can be a valuable adjunct to visual identification. The aim of this study was to evaluate the value of IONM during thyroid reoperation.

A total of 109 patients who met our criteria at the Affiliated Hospital of Hangzhou Normal University from January 2010 to June 2020 were retrospectively analyzed and divided into the IONM group and the visualization-alone group (VA group) according to whether neuromonitoring was used during the operation. The patients' characteristics, perioperative data, and intraoperative information including the RLN identification, time of RLNs confirmation, operative time, intraoperative blood loss, and the rate of RLN injury were collected.

Sixty-five procedures (94 RLNs at risk) were performed in the IONM group, whereas 44 (65 RLNs at risk) were in the VA group. The rate of RLN identification was 96.8% in the IONM group and 75.4% in the VA group ( $P < .05$ ). The incidence of RLN injury was 5.3% in the IONM group and 13.8% in the VA group ( $P > .05$ ). The incidence of surgeon-related RLN injury rate was 0% in the IONM group compared to 7.7% in the VA group ( $P < .05$ ), but the tumor-related or scar-related RLN injury rate between the 2 groups were not significantly different (4.3% vs 3.1%, 1.1% vs 3.1%,  $P > .05$ ).

IONM in thyroid reoperation was helpful in improving the RLN identification rate and reducing the surgeon-related RLN injury rate, but was ineffective in reducing the tumor-related and scar-related RLN injury rate. In the future, multicenter prospective studies with large sample sizes may be needed to further assess the role of IONM in thyroid reoperations.

**Abbreviations:** IONM = intraoperative nerve monitoring, RLN = recurrent laryngeal nerve, VA = visualization alone.

**Keywords:** IONM, nerve visualization alone, recurrent laryngeal nerve, reoperation, thyroidectomy

## 1. Introduction

Thyroid reoperations are relatively rare, but still can be challenging, even for highly experienced surgeons, because of the higher incidence of complications than in primary thyroid surgery, particularly recurrent laryngeal nerve (RLN) injury.<sup>[1]</sup>

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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The RLN is burdened with greater risk during re-thyroidectomy, and the RLN may be displaced in any direction. We can find the nerve adherent to the lateral capsule of the remnant thyroid mass or adheres strictly to the inferior part of a recurrent goiter. Another obstacle in reoperations is massive scarring after the first operation, in which the nerve can be imbedded. A scarred operating field, particularly after subtotal thyroid operations, makes it difficult to find the RLN and separate it from other structures. The incidence of nerve damage was 12.3% for temporary injury and 4.1% for permanent injury according to previous studies.<sup>[2,3]</sup> Unilateral RLN damage causes the absence of movement of the ipsilateral vocal cord and leads to a variety of symptoms related to voice changes, such as vocal fatigue, hoarseness, and dysphonia. However, bilateral RLN damage leads to airway obstruction, which is serious and requires tracheostomy.<sup>[4,5]</sup> RLN paralysis is a serious complication that influences quality of life, including limitations in physical, emotional, and social functioning.<sup>[6]</sup> Thus, it is not surprising that RLN injury is still a major cause of litigation in endocrine surgery, and procedures to reduce the rate of RLN palsy have been the subject of investigation.

Many techniques and strategies are recommended in reoperations to decrease the incidence of RLN injury incidence,<sup>[7-9]</sup> one of which is applying the intraoperative nerve monitoring (IONM). IONM is a technique that can reflect the function of the RLN via the electromyographic signal of vocal muscle

movement.<sup>[10]</sup> The use of IONM has been standardized since 2011.<sup>[11]</sup> In recent years, there have been many publications concerning the introduction of IONM, the learning curve of the new technology, and the assessment of the prevalence of complications when utilizing IONM.<sup>[12,13]</sup> IONM helps to verify the functional integrity of the RLN and aid the surgeon in RLN localization before visualization during thyroid surgery. It is believed that the use of IONM can decrease the rate of RLN injury.<sup>[2]</sup> Previous studies have shown that routine application of IONM in all thyroidectomies did not decrease the rate of RLN palsy.<sup>[14,15]</sup> Few studies have reported the incidence of RLN injury in reoperations with IONM has been published, and only a few studies have compared the RLN injury rate during secondary thyroid surgery using IONM with procedures using only visual RLN identification.<sup>[14,16]</sup> The aim of this study was to investigate whether IONM can aid in RLN identification and reduce the incidence of RLN injury during thyroid reoperations.

## 2. Methods

The study was approved by the Ethics Committee of the Affiliated Hospital of Hangzhou Normal University. We collected information about thyroid reoperations from January 2010 to June 2020 in a retrospective study. Eligible patients fulfilled all of the following inclusion criteria: thyroid operations were carried out at least once before; ipsilateral vocal cord function was confirmed by pre-operative laryngoscopy. Exclusion criteria includes: paralysis of the ipsilateral vocal cord observed by pre-operative laryngoscopy; and previous surgical field and ipsilateral RLNs were not exposed during reoperation. The patients who met our criteria were then divided into the IONM and visualization alone (VA) groups according to the availability of IONM.

All surgeries were completed by a surgical team composed of 3 surgeons who performed approximately 100 to 150 thyroidectomies every year. The team started using IONM for the first time in 2014 during both primary and secondary thyroid operations. All reoperations were performed through an existing skin incision. Different approaches to the remnant tissue were used: the lateral approach, central approach, or the strap muscle transected approach. The RLNs were then located and exposed using different methods.

In the control group, the RLN was identified visually using different anatomic landmarks, such as the Zuckerkandl tubercle, tracheoesophageal groove, and medial aspect of the carotid artery. Once the nerve was visually identified, it was carefully dissected along its course toward the larynx.

In the IONM group, the RLN was monitored using the nerve integrity monitor Response 3.0 (Medtronic Xomed). The connection and use of IONM was performed in accordance with the standard 4-step procedures recommended by the International Neuromonitoring Study Group.<sup>[11]</sup> The carotid sheath in the IONM group was opened to expose the vagus nerves for further stimulation. During dissection, V1, R1, R2, and V2 signals were obtained sequentially by stimulation of the vagus nerve or RLN at given times. The V1 signal was defined as an original EMG signal obtained from the vagus nerve before identification of the RLN; the R1 signal was obtained from the RLN when it was first identified in the tracheoesophageal groove; the R2 signal was also obtained from the RLN after it was completely dissected and its full course in the neck was exposed; and the V2 signal was obtained from the vagus nerve after

complete hemostasis of the surgical field. In addition, stimulation of the vagus nerve or the RLN was performed during challenging or concerning maneuvers. The stimulation current was set at 1 mA. However, 2 mA is sometimes used to map the route of the RLN, which is not seen very clearly.

Fiber-optic laryngoscopy (Karl Storz, Germany) by a throat specialist was mandatory for all patients pre-operatively and postoperatively. Both the identification of the RLN and the RLN injury rate were calculated in relation to the number of nerves at risk. The outcomes of postoperative nerve function were divided into the normal and paralysis groups. RLN paralysis was further divided into surgeon-related, tumor-related, and scar-related injuries according to the causes of damage. Surgeon-related injury refers to accidental RLN damage caused by surgical errors. RLN injury in this group should not be surrounded by scar tissue or invaded by tumors. Tumor-related paralysis was defined as intentional injuries due to perineural invasion by tumors or metastatic lymph nodes, and RLNs were partially or completely transected. Scar-related paralysis was defined as an RLN injury due to tissue adhesion. The surgeon attempted to separate adhesions but failed to protect nerve function. The outcomes of the RLN identification rate, time of RLNs confirmation, operative time, intraoperative bleeding volume, and the rate of RLN injury were compared. All the operations in our study were performed by 1 surgical team, and all patients received IONM after the introduction of IONM, which would eliminate bias caused by patient selection and different surgical techniques.

Data were analyzed using Statistical Product and Service Solutions (SPSS 24.0, American, Chicago) software version 24.0. Continuous variables were analyzed by Student *t* test and expressed as the mean  $\pm$  standard deviation, while categorical variables were analyzed using the chi-square test. Statistical significance was set at  $P < .05$ .

## 3. Results

A total of 109 patients met our criteria and were then divided into the IONM group (37 women and 28 men) and the VA group (24 women and 20 men) according to the available IONM. In the IONM group, there were 65 procedures that exposed 94 RLNs, whereas 44 procedures with 65 RLNs were exposed in the VA group. Table 1 presents patient characteristics. There were no significant differences in age, sex, pathological type, or operation method between the groups ( $P > .05$ ).

The details about the rate of RLN identification, the time of RLN confirmation, operative duration, and intraoperative blood loss are compared in Table 2. The rate of RLN identification was calculated in relation to the number of nerves at risk during the procedure. Only 49 RLNs (75.4%) were identified in the VA group (65 RLNs at risk) and 91 RLNs (96.8%) in the IONM group (94 RLNs at risk), and the difference was statistically significant ( $P < .05$ ). Compared with the VA group, the IONM helps decrease the RLN confirmation time ( $5.3 \pm 2.3$  vs  $6.9 \pm 2.5$  minutes,  $P < .05$ ), and decrease blood loss ( $20.1 \pm 9.5$  vs  $26.5 \pm 12.2$  mL in unilateral and  $29.3 \pm 12.3$  vs  $38.6 \pm 16.9$  mL in bilateral,  $P < .05$ ). Compared with the VA group, the use of IONM did not increase the operative duration in both unilateral ( $87.2 \pm 15.9$  vs  $89.0 \pm 17.0$  minutes,  $P > .05$ ) or bilateral ( $101.1 \pm 16.8$  vs  $106.9 \pm 16.1$  minutes,  $P > .05$ ) procedures.

Information regarding the incidence of RLN injury is presented in Table 3. The study showed that the incidence of RLN injury was 5.3% in the IONM group compared with 13.8% in the VA

**Table 1**  
**Patient's characteristics and information about the reoperation.**

Variables	Frequency	Percentage (%)	Mean	SD	P value
Age (yr)					.397
IONM group			50.92	14.50	
VA group			48.40	15.48	
Gender					.806
IONM group					
Male	28	43.1%			
Female	37	56.9%			
VA group					
Male	20	45.5%			
Female	24	54.5%			
Postoperative diagnosis					.299
Nodular goiter					
IONM group	25	38.5%			
VA group	19	43.2%			
DTC					
IONM group	31	47.7%			
VA group	20	45.5%			
Thyroid adenoma					
IONM group	9	13.8%			
VA group	5	11.3%			
Extent of thyroidectomy					.16
Ipsilateral RTL + lymph node dissection					
IONM group	19	39.6%			
VA group	12	36.4%			
Bilateral RTL					
IONM group	17	35.4%			
VA group	13	39.4%			
Bilateral RTL + lymph node dissection					
IONM group	12	25%			
VA group	8	24.2%			

DTC = differentiated thyroid cancer, IONM = intraoperative nerve monitoring, RTL = residual thyroid lobe, SD = standard deviation, VA = visualization alone.

**Table 2**  
**The operation findings.**

Variables	Frequency	Percentage (%)	Mean	SD	P value
NAR					
IONM group	94				
VA group	65				
Rate of RLN identification, n (%)					<.001
IONM group	91	96.8%			
VA group	49	75.4%			
Time of RLNs confirm (min)					<.001
IONM group			5.3	2.3	
VA group			6.9	2.5	
Operative time (minute)					.669
Unilateral surgery					
IONM group			87.2	15.9	
VA group			89.0	17.0	
Bilateral surgery					.225
IONM group			101.0	16.8	
VA group			106.9	16.1	
Intraoperative blood loss (mL)					.028
Unilateral surgery					
IONM group			20.1	9.5	
VA group			26.5	12.2	
Bilateral surgery					.03
IONM group			29.3	12.3	
VA group			38.6	16.9	

IONM = intraoperative nerve monitoring, NAR = nerve at risk, RLN = recurrent laryngeal nerve, SD = standard deviation, VA = visualization alone.

**Table 3**  
Information about the incidence of recurrent laryngeal nerve injury.

Variables	Frequency	Percentage (%)	P value
NAR			
IONM group	94		
VA group	65		
Rate of RLN injury			
IONM group	5	5.3%	.062
VA group	9	13.8%	
Surgeon-related RLN injury			
IONM group	0	0%	.023
VA group	5	7.7%	
Tumor-related RLN injury			
IONM group	4	4.3%	1
VA group	2	3.1%	
Scar-related RLN injury			
IONM group	1	1.1%	.746
VA group	2	3.1%	

IONM = intraoperative nerve monitoring, NAR = nerve at risk, RLN = recurrent laryngeal nerve, VA = visualization alone.

group, but the difference was not statistically significant ( $P > .05$ ). Compared with the VA group, the use of IONM decreased the incidence of surgeon-related RLN paralysis (0% vs 7.7%,  $P < .05$ ), but the difference was not significant in tumor-related paralysis (4.3% vs 3.1%,  $P > .05$ ) or scar-related paralysis (1.1% vs 3.1%,  $P > .05$ ).

#### 4. Discussion

Thyroid reoperation is a significant challenge for all surgeons because of serious postoperative complications. Surgeons should pay considerable attention to changes in anatomy and scar tissue during reoperation because these changes increase the risk of nerve injury.<sup>[2]</sup> As we all know, surgeon's experience and routine exposure of nerves are 2 crucial point in reducing the RLN injury rate. However, it is difficult to visually distinguish the nerve from the scar tissue and dissect the scar tissue or vessels surrounding the RLN. IONM is a technique that will be helpful in identifying or mapping the path of the RLN and will help in recognizing nerve function.<sup>[11]</sup> However, whether IONM can help prevent RLN injury remains controversial.<sup>[17–19]</sup> Some studies indicated that IONM can be performed safely,<sup>[20]</sup> improve the rate of RLN identification,<sup>[21]</sup> and decrease the rate of RLN injury<sup>[22,23]</sup> during thyroid reoperation. However, most studies hold the opposite opinion.<sup>[19,24,25]</sup> Summarizing these studies, the different results may be due to the small data sample size, the lack of homogeneity among the patients and surgeon's experience, their indications for the procedures, and the extent of surgery. Our study showed that there were no significant differences in age, sex, pathological type, and operation method between the 2 groups (Table 1), which makes our results more reliable.

In our study, both groups of patients had a history of exploration and re-exploration of RLNs. Identification of RLN during thyroid reoperation is sometimes difficult, but IONM may be helpful.<sup>[26,27]</sup> Our results showed that IONM helps to improve the recognition rate of RLN and shorten the confirmation time of RLN compared with the VA group (Table 2). This is because IONM can distinguish the RLN from the vessels and scarred tissue and locate the nerve before visual confirmation. The nerve is mapped out in the paratracheal region through probe stimulation and then visually identified through directed

dissection based on neural mapping.<sup>[28]</sup> In addition, IONM can also improve the identification of rare non-RLNs compared to operations without monitoring according to researches.<sup>[12]</sup> In our study, the frequency of RLN palsy was lower in the group in which IONM was used compared to patients in whom nerves were identified visually (Table 3). The difference between the RLN injury rates in the 2 groups was not statistically significant. In fact, nerve function is sometimes difficult to preserve during re-thyroidectomy because of infiltration by carcinoma or metastatic lymph nodes.<sup>[29]</sup> We were eager to know whether IONM could reduce the incidence of RLN paralysis caused by surgeon-related factors and scar-related factors, but not tumor-related factors. The study showed that IONM can reduce RLN injury caused by surgeon-related factors, but not scar-related or tumor-related factors (Table 3). This is because in thyroid reoperations, the RLN may be displaced in any direction, which can disorient surgeons and lead to inadvertent injury. Using IONM to map the outline of the nerve before any cutting can help minimize damage to the RLN.<sup>[30]</sup> If the RLN is strictly adherent to or imbedded by scar tissue or infiltrated carcinoma, it is difficult to separate it, and the RLN is inevitably injured.<sup>[31]</sup> In a scarred operating field, hemostasis can be difficult because of the high degree of vascularization.<sup>[32]</sup> Our results showed that IONM could minimize bleeding during reoperation (Table 2). This is because IONM is helpful in distinguishing branches of the RLN from the vessels and scarred tissue, mapping the RLN through the overlying tissue.<sup>[21]</sup> Another finding in our study was that the use of IONM did not increase the operation time (Table 2). The study by Sopinski et al<sup>[19]</sup> supports our results. However, in a study by Sari et al,<sup>[33]</sup> all patients undergoing thyroidectomy with the use of IONM had a significantly decreased operative time compared to patients in whom IONM was not utilized. Another retrospective analysis showed increased operative time with the use of IONM.<sup>[34]</sup> The results differ from study to study, perhaps because surgeons are on different learning curves of the IONM. We believe that if surgeons are more skilled, the use of IONM would decrease the operative time.

There are other advantages to using IONM during thyroid surgery. It is worth noting that IONM may guide surgical strategies during reoperations.<sup>[35]</sup> During thyroid reoperation, when a loss of signal is observed on the side of the neck operated on first, a staged thyroidectomy should be considered in order to prevent bilateral nerve injuries.<sup>[2]</sup> For patients who already have unilateral vocal cord paresis, an operation on the contralateral side using IONM will be helpful to guide postoperative care, or even to prompt the surgeon to perform a protective tracheostomy after thyroid surgery.<sup>[36]</sup> It has been proven that staged thyroidectomy can be effective in preventing bilateral RLN injury,<sup>[37]</sup> which has been accepted by many surgeons.<sup>[38–40]</sup> Although the benefit of using IONM for thyroid reoperation may not be indisputable, we hypothesize that if re-exploration near RLNs is planned and performed using IONM, significantly fewer accidental RLN injuries will occur. The use of IONM will also give surgeons more confidence during thyroid reoperation.

There are some limitations to the present study. First, it was a small sample study. Large sample data are needed to draw more expressive conclusions in the future. However, thyroid reoperations are relatively rare, and it is difficult to collect enough samples from a single hospital. The second is the lack of a randomized control trial because we used an IONM device according to the availability of the neuromonitoring system and surgeon preference. In fact, it is very difficult to conduct a

prospective randomized controlled study on this topic. If we select cases from several surgical teams, differences in experience and technique will significantly influence the results. Moreover, it is unethical to place high-risk patients into a control group that does not allow the surgeon to use currently available technology to reduce RLN damage. It should also be recognized that a cost-effectiveness analysis of the utilization of IONM in thyroid reoperations has never been reported and is beyond the scope of this study, and this issue needs to be clarified in the future.

In conclusion, our study showed that IONM was helpful in improving the RLN identification rate, reducing the surgeon-related RLN injury rate, lowering the time of RLN confirmation, and decreasing bleeding during thyroid reoperations. However, it was ineffective in reducing the tumor-related and scar-related RLN injury rate. In the future, multicenter prospective studies with large sample sizes are needed to further assess the role of IONM in thyroid reoperations.

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## Author contributions

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