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ORIGINAL SCIENTIFIC REPORT

# Modification of the Surgical Strategy for the Dissection of the Recurrent Laryngeal Nerve Using Continuous Intraoperative Nerve Monitoring

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## Abstract

*Background* The aim of this study was to describe first experiences and changes in management using continuous intraoperative neuromonitoring (C-IONM) in thyroid and parathyroid surgery.
*Method* Retrospective analysis of patients who underwent surgery with C-IONM since 2012. Surgical maneuvers were modified when electrophysiologic events occurred. Patients with persistent loss of signal (LOS) underwent postoperative laryngoscopy.
*Results* One hundred and one patients (of 1586 neck surgeries) were included and 19 had events: In 13 these were temporary (resolved before end of surgery) and led to intraoperative modifications in surgical approach; in all cases traction was released, and in 8, recurrent laryngeal nerve (RLN) approach was changed [superior approach (2), inferior approach (2), both (4)]. Six patients had persistent LOS (5.9%, present at end of procedure), with RLN palsy (RLNP) on postoperative day 1: In three, LOS occurred at electrode placement on the vagus nerve, leading to distal placement of the electrode allowing ipsilateral dissection under continuous monitoring; all three had complete recovery at 6 months. In the three other patients, LOS occurred on the RLN: one probable thermal, one traction lesion and one accidental section of the anterior RLN branch. The RLN recovered within 6 months in two patients, and in the third, RLNP persisted after 6 months (1/101 = 1%).
*Conclusion* C-IONM provides real-time evaluation of the RLN function, allowing for adaptation of surgical maneuvers to prevent RLNP. It seems particularly useful in difficult cases like redo neck surgery, invasive thyroid cancer and intrathoracic or large goiter. Care should be given at electrode placement on the vagus nerve.

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## Introduction

Recurrent laryngeal nerve palsy (RLNP) is a feared complication of neck surgery and has decreased secondary to routine visual identification of the RLN [1, 2]. Impairment in voice function after unilateral RLNP can greatly affect quality of life and is fortunately transitory in most cases. This is not the case in the dreaded bilateral RLNP [3, 4]. There continues to be a debate regarding intermittent intraoperative neuromonitoring of the RLN (I-IONM), as in recent literature on the systematic use of I-IONM there was no reduction in RLNP rates [5] and the number of patients needed to be treated to avoid a RLN is relatively high [2]. A recent meta-analysis and a randomized study

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show benefit in reducing transient RLNP in complex cases [6, 7]. Another advantage of I-IONM is the prevention of bilateral RLNP, with implementation of strict operative procedures for two-staged thyroidectomy [8] and standardized procedures for I-IONM [9].

Continuous intraoperative neuromonitoring (C-IONM) is a more recent technique and represents the potential for incremental improvement, potentially enabling the surgeon to react before irreversible damage to the RLN occurs [10, 11]. An electrode is placed on the vagus nerve during the entire operation in order to measure the electromyographic activity of the muscles innervated by the RLN. The lesions to the RLN are most frequently caused by traction, followed by clamping, transection or thermal injury, as shown in a recent multicenter study with 80% of 115 cases with loss of signal (LOS) caused by traction to the RLN [12]. The difference between each type of injury is critical when it comes to C-IONM because not all of them can be prevented by IONM, and because traction injuries, if tension is released when detected early by IONM, are reversible. This has been shown in porcine models [13, 14] and in humans, with Phelan [11] and Schneider et al. [10] showing that more than 73 and 82% of events, respectively, were reversible during surgery when prompt corrective measures were applied. When comparing RLNP between I-IONM and C-IONM, they conclude that C-IONM offers a higher sensitivity for early postoperative RLNP [10]. Furthermore, a safety analysis of 400 vagal nerve dissections and electrode positioning was reported to be safe [15]. On the other hand, Terris et al. [16] report one case of bradycardia and hypotension using the vagal electrode and one case of trauma to the vagal nerve by electrode application with LOS resulting in temporary RLNP, concluding this to be an invasive and harmful technique. Another group looking at high-risk neck surgeries reports one LOS caused by the vagal electrode and multiple situations of electromyographic (EMG) artifacts [17].

C-IONM was introduced in Geneva in 2012 and used selectively in difficult surgical cases such as re-interventions, invasive cancer, retrosternal goiter and Graves' disease. In the present study, we aim to present our experience with C-IONM.

## Methods

This is a retrospective single-center study of consecutive neck surgery cases with C-IONM conducted between August 2012 and October 2016 at the University Hospitals of Geneva. This study was approved by the Institutional Review Board.

The University Hospitals of Geneva are a tertiary center with approximately 400 thyroid and parathyroid surgeries per year, and the use of I-IONM is standard of care since 2008 [9], as well as two-staged thyroidectomy in cases of LOS on the first side, as published by our group [8].

The choice to use C-IONM was decided intraoperatively by the surgeon, based on expected difficulties, and used selectively in difficult cases. Combined use of handheld probe for RLN identification and continuous electrode on the vagal nerve was done in all cases. The vagal nerve was dissected for the placement of a 2- or 3-mm-diameter-sized automatic periodic stimulation (APS®) electrode (Medtronic), with baseline calibration, and the size of the electrode was decided by the surgeon after vagal nerve visualization. Patients were intubated using commercial EMG endotracheal tubes, and NIM-Response 3.0 system was used for monitoring (Medtronic Inc., Jacksonville, USA).

All procedures were performed by two surgeons (each with annual volume >100/year), using a standard approach: lateral approach to the RLN after medializing the thyroid and using energy devices (harmonic focus®). If significant events associated with a surgical maneuver occurred, that maneuver was immediately aborted and another approach was performed. A LOS was defined as a response in EMG below the threshold of 100 μV. An event was defined as a decrease >50% of EMG amplitude from baseline or an increase in latency of more than 10%, with an acoustic signal to the surgeon. LOS was classified into type 1 (segmental) and type 2 (diffuse) injuries. All events and changes in surgical maneuvers were recorded. In cases of LOS, direct laryngoscopy (DL) was performed by our ear–nose–throat (ENT) specialist at postoperative day (POD) 1, and at follow-up. Current practice is follow-up at POD10 and patients with LOS are enrolled in a protocol with ENT follow-up of RLNP and therapy, or until resolution of paresis. Transient and permanent RLNP was defined as resolved within or present at 6 months after surgery, respectively.

Exclusion criteria were patients with RLNP on preoperative laryngoscopy and thyroid cancer invading the RLN (intentional section).

Descriptive analyses were performed to determine the incidence of RLNP and changes in surgical approach. Fischer's exact test was used for comparisons. Two-tailed $P < .05$ was considered statistically significant. Continuous data are presented as mean ± standard deviation (SD) or median [range], as appropriate. Statistical analyses were performed using SPSS, version 21 (IBM®).

## Results

Between August 2012 and October 2016, 101 patients with 159 nerves at risk were included using C-IONM, from a total of 1586 neck surgeries performed over the same time period. Mean age of patients was 55 ± 16.8 years, with 65.4% being female, as shown in Table 1. The average time of surgery was 156.6 ± 63.5 min and the most frequent indication for surgery was benign disease (63.4%, comprising 24.8% of retrosternal or large compressive goiters), and suspected malignancy in 36.6%. Overall, 41.6% total thyroidectomies were performed and 14.9% with neck dissections, 25.7% unilateral lobectomies, 8.9% completion surgeries, 4.0% neck dissections and 4.9% parathyroidectomies. On pathology, 36.6% had malignant disease, with 14 patients presenting stage III and IV disease.

### Loss of signal with C-IONM and modification of surgical maneuver

In all cases, the electrode placement was successfully achieved after dissection of the vagal nerve. C-IONM did not result in any intraoperative anesthesiological events. Overall, in 19 cases an event was observed (19/101 = 18.8%). Thirteen patients had temporary events (resolved before end of surgery) and six had a persistent LOS (no signal at the end of the procedure). In all, the current maneuver provoking the events was aborted and traction released to wait for an increase in signal.

The 13 temporary events led to the following modifications in surgical approach: In five cases, traction was released, and in eight cases, in addition to traction release, the surgical strategy for RLN approach was changed, in two patients, a superior approach, in two an inferior approach and in four both approaches were used.

The six patients with persistent LOS (6/101 = 5.9%) are listed in Table 2. All six had a unilateral RLNP confirmed at DL on POD1. Histopathology showed one case with recurrent central lymph nodes of papillary thyroid cancer (PTC), one PTC with lateral and central lymph nodes, one PTC, two large goiters and one case of Grave's disease. In three cases LOS occurred at electrode placement, with the vagus nerve anatomically intact and no visible lesions (cases 4–6). The IONM signal was lost on the proximal side of the electrode, which led to distal placement of the electrode on the vagus nerve. Ipsilateral dissection was then performed with C-IONM. In two cases, the planned bilateral surgery was interrupted after the first side due to LOS, with RLNP confirmed at POD1. They both had a complete recovery of RLN within 2 months, followed by surgery on the second side. In the third case, with previous lateral and central neck dissection, DL showed RLNP on POD1, but complete recovery at 6 months.

In the other three cases (cases 1–3), only lobectomy was planned or LOS happened on the second side: One case had LOS probably due to traction with an anatomically intact RLN, and RLNP at POD1 but full recovery within

**Table 1** Clinical characteristics of cohort with C-IONM ($n$ = 101)

| Variables | Values |
|---|---|
| Mean age in years | 55 ± 16.8 |
| Female gender | 66 (65.4) |
| Mean body mass index (kg/m$^2$) | 26.3 ± 5.4 |
| ASA score | |
| ASA1 | 10 (9.9) |
| ASA2 | 80 (79.2) |
| ASA3 | 11 (10.9) |
| Mean duration of surgery (min) | 156.6 ± 63.5 |
| Indication for surgery | |
| Benign[a] | 52 (51.5) |
| Suspect nodule[b] | 15 (14.9) |
| Malignant (PTC, FTC, MTC, ATC) | 22 (21.8) |
| Grave's disease, Hashimoto thyroiditis | 12 (11.9) |
| Type of surgery | |
| Total thyroidectomy | 42 (41.6) |
| Thyroidectomy and neck dissection | 15 (14.9) |
| Unilateral lobectomy | 26 (25.7) |
| Completion thyroidectomy | 9 (8.9) |
| Neck dissections | 4 (4.0) |
| Parathyroidectomy | 5 (4.9) |
| Pathology | |
| Benign[c] | 54 (53.5) |
| Grave's disease, Hashimoto thyroiditis | 10 (9.9) |
| Malignant | 37 (36.6) |
| PTC (including micro-papillary)/FVPTC | 15/14 |
| FTC | 2 |
| MTC | 2 |
| PDTC/ATC | 3/1 |
| Stage[d] I/II/III/IVa + IVb | 21/2/6/7 + 1 |
| Number of nerves at risk, total | 159 |
| Unilateral | 43 |
| Bilateral | 58 |
| EMG events, total | 19 |
| Events, temporary | 13 (12.9) |
| Persistent LOS | 6 (5.9) |
| RLNP | |
| Temporary | 6 (5.9) |
| Permanent | 1 (1.0) |

Values are presented as mean ± standard deviation or $n$ (%)

[a]Multinodular goiter, toxic nodules, chronic thyroiditis, cystic lesions, hyperparathyroidism

[b]Suspect nodules (Bethesda classification III–V) and non-specific tumors

[c]Thyroid hyperplasia and follicular adenoma, multinodular goiter, parathyroid hyperplasia and adenoma, cysts

[d]According to the AJCC Cancer staging Manual, 7th edition [25]

*ASA* American Society of Anaesthesiologists, *ATC* anaplastic thyroid carcinoma, *EMG* electromyographic, *FTC* follicular thyroid carcinoma, *FVPTC* follicular variant PTC, *MTC* medullary thyroid carcinoma, *PDTC* poorly differentiated thyroid carcinoma, *PTC* papillary thyroid carcinoma, *RLNP* recurrent laryngeal nerve palsy

1 month; one case had possible thermal lesion, with RLNP at DL and recovery within 6 months; in the last case, there was an accidental section of the anterior branch of RLN, with suture of nerve extremities during surgery, and with persistent RLNP at DL. Overall, there was one persistent RLNP in this cohort (1/101 = 1%).

Analyzing risk factors for RLNP and LOS, such as redo neck surgery, neck dissections, invasive thyroid cancer and intrathoracic or large goiter, none were found to be significant for RLNP.

Twelve patients presented transient postoperative hypoparathyroidism and two had persistent hypoparathyroidism at 6 months. Three patients presented non-surgical postoperative hematoma.

### Comparison with loss of signal using I-IONM

Of all 1586 cases performed using I-IONM during the same time period, 64 patients had persistent LOS, with 42 cases presenting with RLNP at POD1 (42/1485 = 2.8%, excluding those who underwent C-IONM), and in 22 of the cases, the DL on POD1 was normal (I-IONM with false positive LOS or early recovery of RLNP).

Analyzing the causes of LOS, there were 26 due to traction mechanism (26/64 = 40.6%), of those 20 had RLNP on POD1. Eleven presented with difficult dissection around the RLN due to adhesions, three had thermic injury to the nerve, one accidental section, two after compression (for bleeding) and the rest was unknown.

RLNP persisted in 13 patients at 3 months, and in one patient at 6 months. Three patients were lost to follow-up.

## Discussion

This study presents the first 101 cases performed with C-IONM in neck surgery at the University Hospitals of Geneva. The results show that in 13 patients the events were temporary after a change in surgical approach was performed and prevented a LOS from occurring. In three cases, LOS occurred at electrode placement on the vagal nerve and in one case with an accidental section of the anterior branch of RLN, RLNP persisted after 6 months (1/101 = 1%).

Our findings reveal a direct risk to the vagal nerve by electrode placement in three cases, resulting in a rate of RLNP at POD1 due to the electrode of 2.97% (=3/101 cases, or 1.9% = 3/159 nerves at risk). The vagal nerve was intact in all three cases, and placement was carefully performed under direct vision, without hematoma. The exact reason for this trauma is unclear, but might be due to perineural bleeding or traction by surgical instruments when exposing the nerve. In our first case (Grave's disease, #4), the dissection was not particularly difficult but the vagal nerve was positioned posterior and deep to the vessels. In the second case (recurrent PTC, #5), vagal nerve dissection was difficult, because the patient had undergone previous central and lateral lymph node dissection. And in the third case (PTC N1b metastasis, #6), the vagal nerve was dissected full length for the lateral neck dissection. Also, the signal was lost proximally to the electrode and RLNP was transient in all three cases. Only a few such cases have been described in the literature, with Brauckhoff et al. [17] citing two cases of LOS by the electrode in high-risk surgery, one at placement due to perineural bleeding, and one caused by an undetected torsion of the electrode. Mangano et al. [15], in a safety study of 400 vagal nerve dissections and electrode placements, report a mean increase in vagal nerve size after electrode placement of .82 mm and an electrode dislocation rate of 11% per procedure, thus highlighting the importance of selecting the suitable electrode size and using careful, standardized technique of vagal nerve dissection and electrode placement. Every new surgical technique has a learning curve [18]. The three LOS at electrode placement occurred over the 5-year study period, the last case happening after standard dissection of more than 100 vagal nerves. This led us to believe that LOS might be caused by the upward traction of the right-angle dissector used for the 360° nerve dissection necessary for electrode placement. We believe it is mandatory to verify the signal on the vagus nerve above the site of electrode placement (proximal) at the end of surgery, in addition to the C-IONM signal from the electrode, as this is not sufficient to guarantee postoperative RLN function.

With regard to the 13 temporary events (13/101 = 12.9%), the decrease in amplitude of the initial IONM value was seen when medializing the thyroid. The most logical explanation for this phenomenon is the mobilization of the thyroid, which causes the nerve to stretch and leads to a decreased conduction capacity. The perioperative solution in response to C-IONM was to release the traction, which in addition to a change in approach, led to full recovery of all RLN signals. Going further, we could assume that some of the 26 traction injuries in the I-IONM cases could have been avoided if C-IONM had been used, as the traction would have been immediately released before definitive injury occurs. This concurs with findings from other studies that report events to be reversible when prompt corrective measures are applied during surgery [10, 11, 19]. Thus, our study shows that the RLN recovers when appropriate measures are taken.

We had one case of accidental section of the anterior RLN branch while using C-IONM, resulting in an overall permanent RLNP rate of 1% (1/101 cases). This RLNP was

**Table 2** Cases with intraoperative loss of signal at C-IONM

| Case | Age sex | Planned surgery | LOS type | LOS cause | Surgery change | Pathology, TNM | Size/ weight | DL D1 | Second DL at follow-up | Follow-up |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 78 m | Total thyroidectomy | 2 | Traction, on second side | Release of traction<br>No change for approach RLN | FV PTC, T1b (m) | 1.2 cm | uRLNP | M1: no uRLNP | |
| 2 | 44 m | Total thyroidectomy | 1 | Section of ant. branch RLN, on second side | No change for approach RLN | MNG | 96 g | uRLNP | M6: uRLNP | |
| 3 | 50 f | Lobectomy | 1 | Thermal lesion | Superior approach to RLN | MNG | 92 g | uRLNP | M6: no uRLNP | |
| 4 | 51 f | Total thyroidectomy | 1 | LOS at electrode placement on vagus nerve | Distal placement of electrode<br>Stop after 1st side | Grave's disease | 62 g | uRLNP | M2: no uRLNP | M2: Surgery 2nd side |
| 5 | 49 f | Recurrent CND | 1 | LOS at electrode placement on vagus nerve | Distal placement of electrode | Metastatic LN PTC (3/19) | 3.8 cm | uRLNP | M6: no uRLNP | |
| 6 | 48 f | Total thyroidectomy, LND and CND | 1 | LOS at electrode placement on vagus nerve | Distal placement of electrode<br>Superior approach to RLN<br>Stop after 1st side | PTC T3 N1b (7/16) | 2 cm | uRLNP | D15: no uRLNP | D15: Surgery 2nd side |

*CND* central lymph node dissection, *D* day, *DL* direct laryngoscopy, *f* female, *FV PTC* follicular variant of papillary thyroid cancer, *g* gram, *LN* lymph node, *LND* lateral lymph node dissection, *LOS type* loss of signal: type 1 = segmental; type 2 = global, *M* month, *m* male, *MNG* multinodular goiter, *RLN* recurrent laryngeal nerve, *uRLNP* unilateral recurrent laryngeal nerve palsy

not prevented by C-IONM and reflects a segmental LOS, which is caused by abrupt trauma, such as thermic, transection or clamping. These segmental lesions usually happen without delay and do not permit the surgeon to take protective action, contrary to the gradual, global LOS due to traction. They are therefore a limitation of C-IONM.

Overall, both permanent and temporary RLNP rates were similar to another study using C-IONM in high-risk neck surgeries [17]; however, they were higher than in other studies, which had no permanent RLNP using C-IONM [10] when compared to I-IONM [11]. Furthermore, no risk factors for RLNP have been found, looking at extent of disease and difficulty of surgery.

Regarding the risk of dislocation of the electrode during surgery, cited by other studies to be between 11 and 30% [11, 15], we feel that the most important factor causing dislocations is the surgical maneuvers used when placing the electrode and during thyroid surgery. Our group dissects the vagal nerve staying underneath the sterno-thyroid and sterno-hyoid muscles. Certain groups have used an entirely lateral approach (to the muscles) or even going in between the pre-thyroidal muscles [20] for access. Retracting carefully and laterally the pre-thyroidal muscles seemed to distance the electrode from the surgical field and protect it from dislocations. Usually, the electric wire and its electrode were not touched by the retractors and thus not under traction.

Also, as mentioned before, a two-staged thyroidectomy is performed at our center in case of LOS on the first side [8]. This approach is controversial and not always used by other teams [21, 22], but we prefer this approach in order to avoid the risk of bilateral RLNP, and patients are informed prior to surgery and understand the reasoning. A recent study also suggests that this approach is cost-effective [23].

The present study has limitations. First, the number of patients with C-IONM was limited, as they were only high-risk cases, depending strictly on the perioperative decision of the surgeon. This introduces a selection bias in the comparison with I-IONM. Second, due to the non-randomized study design, the final conclusion regarding the potential benefit of C-IONM is weakened, and the small number of events did not allow for robust analysis. Last, the use of pre- and postoperative laryngoscopies was not systematic, which limits the interpretation of the study's results regarding RLNP and outcome of C-IONM. To obtain more reliable outcome data regarding C-IONM, future randomized studies are needed.

In conclusion, C-IONM provides a real-time evaluation of the RLN function, allowing for adaptation of surgical maneuvers to prevent RLNP. Because it implies a risk at electrode placement, the risk–benefit ratio of C-IONM should be further evaluated. In our opinion, C-IONM is particularly useful in situations where the RLN is difficult to identify by the standard lateral approach, like in redo surgery, in patients with posterior nodules or with large and/or retrosternal goiters. In these latter situations (large and retrosternal goiters), we favor a superior approach to the RLN (also called the toboggan technique [24]) and find C-IONM very helpful for this technique. Furthermore, when using C-IONM, we believe that a vagal stimulation above the site of electrode placement should be performed at the end of dissection to ensure integrity of the vagal nerve and RLN and to avoid false negative IONM result (a good IONM signal with true RLNP).

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**Compliance with ethical standards**

**Conflict of interest** All authors declare that they have no conflict of interest.

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