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ORIGINAL ARTICLE

The role of intraoperative neuromonitoring in preventing lesions of the spinal accessory nerve during functional neck dissection

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Abstract

Intraoperative neuromonitoring (IONM) in thyroid surgery offers a valid aid to the operator in identifying the recurrent laryngeal nerve and preserving its function. Recently, IONM has also been used in other surgeries, such as spinal accessory nerve dissection, during lymphectomy of the II, III, IV, and V laterocervical lymph nodes. The goal is the preservation of the spinal accessory nerve, whose macroscopic integrity does not always indicate its functionality. A further difficulty is the anatomical variability of its course at the cervical level. The aim of our study is to assess whether the use of the IONM helps to reduce the incidence of transient and permanent paralysis of the spinal accessory nerve, compared to "de visu" identification by the surgeon alone. In our case series, the use of the IONM reduced the incidence of transient paralysis, and no permanent paralysis was recorded. In addition, if the IONM registers a reduction in nerve potential, compared to the baseline value during surgery, it could indicate the need for early rehabilitation treatment, increasing the patients' chances of regaining function and reducing the costs of prolonged physiotherapy treatment.

Keywords Accessory nerve · Neuromonitoring · Laterocervical lymphadenectomy · Thyroid cancer · Nerve injury

Introduction

In the last decades surgery has been revolutionized by technical innovations like the rise of mini-invasive surgery or the application of new technologies to improve the safety of the operation both for the surgeons and for the patients. Intraoperative neuromonitoring (IONM) represents an important example of this technological development and it has gained a widespread role in several surgical fields in the latest years.

IONM allows the surgeon to have a visual and acoustic feedback on the integrity of the nerves and it plays an important role in reducing the incidence of post-operative nervous complications, including transient and permanent nerve's palsy [1, 2].

For this reasons IONM has been widely applied during thyroid and parathyroid surgery to minimize iatrogenic intraoperative lesions of the recurrent laryngeal nerve [3, 4]. Furthermore IONM was recently used in laterocervical neck lymphadenectomy, mostly for the identification of the spinal accessory nerve (SAN) and so for its safe dissection [5]. In fact, spinal accessory nerve palsy results in weakness or complete loss of strength in trapezius muscle, causing limitations in shoulder's movements, muscular and articular pain and a syndrome known as "shoulder syndrome" [6–8].

The prevalence of this complications is often underestimated and it can occur even when the SAN is anatomically preserved.

The aim of our study is to assess the feasibility and safety of the use of IONM in functional radical neck dissection (FRND) with a focus on its role in preventing and predicting spinal accessory nerve's lesions and so the functional outcomes of neck dissection surgery.

Materials and methods

We enrolled consecutively patients with laterocervical lymph nodes metastasis for thyroid cancer treated with FRND. This retrospective study was conducted between 2016 and 2021 at the Thyroid and Parathyroid Unit of Sant'Andrea Hospital, department of Medical and Surgical

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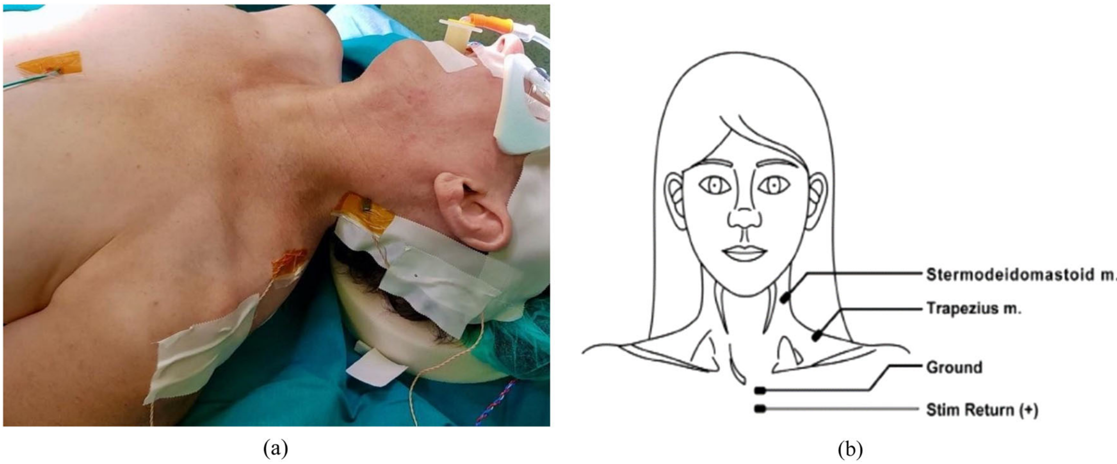

Fig. 1 **a** Position of the electrodes in the operating setting; **b** theoretical position of the electrodes for SAN neuromonitoring

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We report the results in terms of transitory and/or permanent palsies of the accessory spinal nerve between two group: group A treated with the "de visus" identification of the nerve and group B with the aid of IONM [9].

Inclusion criteria were age between 18 and 70 years old, diagnosis of cervical lymph node metastases from thyroid cancer which require FRND and BMI between 18 and 30. To make the sample homogeneous, we chose patients with a BMI that excluded technical difficulties related to a larger presence of fat tissue.

The presence of lymph node metastases was assessed with preoperative ultrasound and confirmed by fine needle aspiration cytology.

Exclusion criteria were reoperation, previous radiotherapy on the neck, neuromuscular diseases, previous surgery on the neck and shoulder area, previous damage of the SAN, tumor invasion of the nerve, pathological N1 with any metastatic lymph node >3 cm in diameter [10]. In our opinion large lymph nodes tend to make more tenacious connections with anatomical structures, thus making surgical dissection more difficult. In fact, in terms of the technical difficulty of lymphectomy, it is not so much the number of metastatic lymph nodes that counts, but their size.

Demographic data were recorded and included age, gender and pre-operative diagnosis.

All patients were operated by the same experienced endocrine surgeon (more than 100 procedures per year) [11]. All patients underwent FRND for laterocervical lymphadenopathies and neck lymph node levels II-III-IV-V were dissected according to the American Academy of Otolaryngology system [12]. An informed consent was obtained from every patient before all procedures.

In our department routine application of IONM during laterocervical lymphadenectomy was introduced in 2018. Therefore, from 2016 to 2018, Thirty-two patients were treated without IONM and 31 of them fit the inclusion criteria to be included in group A. Thirty-five patients underwent surgery between 2018 and 2021 with the help of IONM and 33 of them fit the inclusion criteria to be included in group B.

The device used for group B was NIM-Response® 3.0 System (Medtronics, Minneapolis, MN) in all cases. Two muscular-cutaneous electrodes were positioned by the posterior edge of the sternocleidomastoid muscle (SCM), one in correspondence of the II lymph nodes level [12] and the second one on the descending margin of the trapezius muscle. Two intradermic electrodes were positioned on the anterior thoracic wall, one for the grounding and one for the registration of the stimulus [5] (Fig. 1).

The SAN was visually identified during the surgical dissection in all procedures for both groups. In particular at the II level the nerve was detected before the entrance in the anterior triangle of the neck among the internal jugular vein (IJV) medially, the SCM laterally and the inferior margin of the posterior belly of the digastric muscle superiorly (Point 1). At the V level the SAN was identified after its exit at the posterior margin of the SCM, one centimeter above the Erb's point (Point 2) [13].

In the patients treated without the aid of IONM (group A), the integrity of the nerve was evaluated and preserved only with visual identification.

For group B the identification of the SAN was helped by IONM. The baseline value of the potential of the nerve was evaluated at Point 1, using mapping method, the electrophysiological values recorded at this point represent the baseline (S1) [14]. Electrophysiological data was recorded at Point 2.

Table 1 Constant-murley score (CMS)

Subscales	Points
pain	15
adls (activities of daily living)	20
rom (range of motion)	40
strenght	25
total	100

A loss >50% of the amplitude of the potential and/or an increase of the latency time of the potential > of 10% were considered suggestive for functional damage of the nerve [14].

Results in terms of transitory and/or permanent palsy of accessory spinal nerve and number of lymph nodes dissected in the two groups were compared.

All patients were clinically evaluated preoperatively, at the time of discharge, one months after the surgery and at the end of the rehabilitation program (when it was required). The assessment of the shoulder muscular functionality and the associated pain was performed using the Constant-Murley Score (CMS, Table 1) which is the gold standard in the evaluation of shoulder disfunction (ESSE 2008) [15–17].

Patients with a reduction of the Constant-Murley Score underwent electromyography that confirmed a motor deficit of the trapezius muscle. Permanent palsy was defined as a lack of recovery of Constant-Murley Score between normal ranges after 6 months of physical therapy [7, 18].

Statistics

All data were initially entered into an EXCEL database (Microsoft, Redmond Washinton-USA) and the analysis was performed using SAS software (Version 9.4). The statistical significance of the categorical variables was evaluated using the Fisher's exact test, whereas Student's *t* test was used for the analysis of continuous variables. A *P* value < 0.05 was considered statistically significant. Descriptive statistics consisted of the mean ± standard deviation for parameter with normal distributions and median and range (Min; Max) for variables with non-normal distributions.

Results

A total of 64 patients were included in this study (Table 2) 50 women and 14 men. Mean age was 52.68 yo, median was 54 yo. Thirty-one patients (group A) underwent FRND surgery without IONM from January 2016 to June 2018; while 33 patients (group B) underwent FRND with IONM from July 2018 to January 2021 (Table 2). Mean age ad standard deviation for Group A was 52.87 ± 9.49 (range 33–70 y); for Group B 52.12 ± 10,2 (range 33–67 y). No statistically significant differences in age and sex ratio and thyroid disease type were found between the two groups (Table 2).

The average number of lymph nodes detected was 27.32 ± 3.12 in group A and 26.76, DS ± 3.32 in group B. No statistically significant difference between the two groups was shown ($p = 0.4889$).

Seven patients in group A showed a decrease in CMS from 100 before the surgery to 60–85 one month after surgery.

Patients of this subgroup started physical rehabilitation 40 days after surgery and followed a standardized program for 4 months. At the end of the rehabilitation program three patients registered an increase of the CMS reaching values between 87 and 95 points, recovering almost completely the shoulder functions. In the remaining four patients functional deficit and shoulder's soreness didn't disappear or improve at all in accordance with a permanent palsy of the SAN.

Out of 33 patients of group B who underwent surgery with the aid of IONM, only 2 registered some signs of neuronal damage of the SAN, with a reduction greater than 50% in the amplitude of the potential of the SAN and/or an increase of the latency time of the potential greater the 10% during the procedure. The CMS assessed at discharge in these two patients was 79 and 81. Physical therapy was started precociously, after 20 days from surgery. The evaluation at one month showed a reduction of the shoulder girdle soreness and an improvement in shoulder functionality, supported by a CMS of 97 and 95, respectively in the two patients.

In group A the rate of lesions of the SAN was 22.58%, resulting in seven transitory palsies of which four (12.90%) evolved in a permanent deficit of the shoulder girdle and three (9.68%) regressed thanks to physical therapy.

In group B the rate of lesions was 6.06% (2 patients with transitory palsy); the alterations of the SAN were recordered intraoperatively thanks to the IONM and confirmed by a reduction of the potential at the end of the procedure, but none of these exited in a permanent palsy and patients had a full recovery after one month of physical therapy (Fig. 2).

The use of IONM proved to be statistically significant in the reduction of permanent palsy ($p = 0.0495$) and, even if the rate of transitory palsy was not statistically significant ($p = 0{,}460$), it was inferior in the group treated with IONM (2 vs 3).

We also analyzed the impact of the treatment based on the differences between the incidence of lesions in the two groups and emerged that, with the use of IONM, every 100 surgical operations we can prevent 8.52 lesions.

Table 2 Characteristics of the two groups

Type of group	N of patients	Age (y) ± ds	Ratio (female:male)	Papillary Carcinoma (PC)	Medullary Carcinoma (MC)
A (No IONM)	31	52.87 ± 9,49	25:6	24	7
B (IONM)	33	52.12 ± 10,2	25:8	31	2

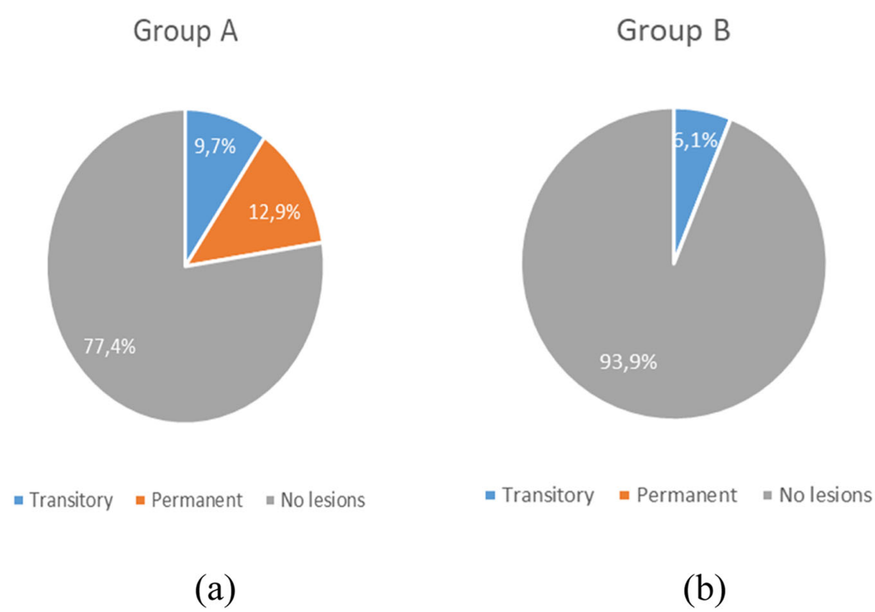

Fig. 2 **a** Percentage of lesions in group A; **b** Percentage of lesions in group B

In terms of oncological radicality we didn't find a significant difference in the number of lymph nodes harvested between the two group. Although there is no clear evidence of minimum number of lymph nodes required to define a FRND effective, in high volume departments the average number of lymph nodes dissected is 26 and so our data correspond with the current literature [10, 12, 19].

Discussion

SAN palsy remains the most common complication after FRND and, in literature, it was estimated between 13 and 50% [7, 20, 21].

The great variability derives from the wide range of surgical indications to perform a FRND and from the types of postoperative outcome considered in different studies, such as post-operative pain, electromyographical findings or shoulder functionality test [22–24].

The injury of the nerve and the subsequent denervation of the trapezius muscle has been associated with shoulder pain and functional loss, in a clinical picture defined as "shoulder syndrome" [8]. The most common findings include shoulder drooping, limited later abduction and scapular rotation and all of them resulted in pathological electromyographic records [25, 26].

The SAN is exceptionally susceptible to injury, due to the inconstant anatomy and its superficial position in the posterior triangle. Indeed, the course of the SAN, especially across the posterior triangle is extremely various [27–29]. Moreover, the patient position during surgery (neck hyperextended, head extra-rotated) does not correspond to the position in which reference points are set by anatomists [13, 28].

The anatomical descriptions of the exact course of the SAN and of the nearby structures given in the literature are surprisingly inaccurate and often conflicting.

A cadaver anatomical study written in 2000 by Kierner et al. [13] showed that in the anterior triangle of the neck the SAN crossed the IJV ventrally and dorsally respectively in the 56 and 44% of the cases. While, in the posterior triangle, in 63% of the cases the SAN enters behind the posterior border of the SCM and in the 37% of the cases passes in front of the muscle; only in one third of the cases SAN enters the SCM and leaves it at different levels.

According to the same study, the nerve enters the trapezius muscle with a single branch only in the 9% of the cases, while in the 61 and 30% of the cases splits repeatedly in two or three branches 2–3 cm before its entrance [13, 27].

The trapezius muscle is innervated by branches of both the SAN and cervical plexus (C2–C4), being the SAN more represented in the descending portion [30, 31]. These redundancies are crucial when an iatrogenic lesion of eithers structures occurs because it contributes to maintain a certain functionality of the shoulder gridle and to allow some sort of recovery even with partially compromised nerves.

A macroscopically intact accessory nerve does not necessary correspond to a healthy and functional nerve. Several studies have shown that even after nerve-sparing procedures abnormal electromyograms were reported; although after such procedures, with a proper rehabilitation, the electromyographical activity tends to improve or normalize with time [24, 32].

In our opinion IONM represent a breakthrough in FRND due to the high anatomical variability of the nerves involve in that dissection.

First of all, IONM facilitates the safe identification of the SAN in a region crossed by several structures often with an intersecting course, therefore it allows a considerable reduction in operative time and in a more satisfying lymphadenectomy because the surgeon feels more confident in his gestures once he has certainly identified the nerve. In fact, SAN injuries usually don't occur during the dissection of the nerve, but they frequently occur during its difficult research before the first visualization and identification. The high voltage neuromonitoring mapping phase (2.5 mA) allows to restrict the research area and to motivating the surgeon to a wide and comfortable exploration of the surgical field. In fact, once the electromyographical signal is detected, the surgeon proceeds more confidently with the dissection until a visual identification of the nerve is reached, avoiding unexpected bleeding, useless and dangerous maneuvers near to crucial anatomical structures.

With the aid of IONM stimulation, we were able to detect an atypical electrical activity of the nerve, in terms of decrease of amplitude or increase of latency of the signal. The evaluation of these parameters can reveal a possible damage invisible to the human eyes due, for example, to an excessive stretch of the nerve or improper use of electrocautery.

In our series, we reported a frequency of permanent palsies of 12.90% in patients undergoing the standard surgical technique. Whereas no permanent palsies was registered when the FRND was performed with the aid of IONM. Therefore, we had a statistically significative reduction of the rate of permanent palsies in patients treated with IONM. In fact, only two patients in that group experienced a loss of potential during the surgery but, because of the early diagnosis, they took advantage of early physical therapy with a complete recovery within two months.

Some studies have shown that, postoperative early rehabilitation (between 15 and 45 days after surgery) can improve the shoulder functionality because early movements reduce scapulohumeral girdle stiffness and capsular fibrosis, facilitating early recovery and relieve of pain [7]. On the contrary, the lack of early diagnosis and rehabilitation can lead to adhesive capsulitis, a chronic condition difficult to reverse [26, 33]. The use of IONM can not only reduce the damages of the nerve but also simplify the early diagnosis.

Our experience allowed us to focus on some steps of the procedure to easily understand electromyographical results. At first, the research for the SAN needs to be started in the anterior triangle, laterally to the IGV, underneath the posterior belly of the digastric muscle and the electromyographical values of amplitude and latency must be taken as baseline. There are several connections between the SAN and the cervical plexus branches that could provide false positive signal during the mapping. The electrodes must be placed in the ascendant part of the trapezius, making more likely that the intraoperative signals result from the SAN stimulation rather than from C2-C4 branches stimulation [31, 34]. For the same reason, once the SAN is identified in the anterior and posterior triangle, it's mandatory to follow it and stimulate it with very low voltage (0.8 mA). At the end of the lymphadenectomy the integrity of the SAN is confirmed by the signal obtained stimulating the nerve at the level of its entrance in the posterior triangle, that must be equal to the signal taken as a baseline. At this point it is appropriate to disconnect the muscular-cutaneous electrode on the sternocleidomastoid to be sure that the recorder potential originates from the SAN. With these passages we have been able to properly use the IOMN as a guide for the dissection and to detect immediately possible lesions.

Conclusions

In our series we have shown that IONM is a safe and effective procedure during FRND and it can reduce the number of SAN iatrogenic injuries with a statistically significant difference in the number of permanent lesions ($p = 0.0495$). It requires a very short learning curve, especially for surgeons with basic knowledge in intraoperative neuromonitoring and there is no increase in operative time after a short period of training. The early diagnosis performed with the aid of IONM and therefore the precocious start of rehabilitation treatments allows a high rate of recovery from the transitory palsy and lead to a reduction in healthcare costs for the management of these patients.

In consideration of our experience in thyroid and neck dissections surgery we found that, after the introduction of the IONM in our surgical routine, the surgeon was allowed to complete the dissection more confidently and safely leading to an easier and harmless identification of the SAN.

We believe that this allows a reduction in the operating time required for the dissection, even if we are not able to provide data about it.

Several studies have used electromyography to evaluate the trapezius's innervation and the effect of the SAN lesions on the potential generated. Those data had been correlated with the possibility of recovery of the SAN after iatrogenic lesions [5, 35]. However, to our knowledge, our study is the first to compare two homogeneous groups of patients undergoing lateral neck dissection performed by the same experienced surgeon, with and without the aid of IONM to assess the effect of these procedure in reducing post-operative palsies.

This study has many limitations, like the small number of patients involved or the absence of randomization. We hope that in the future more scientifically rigorous and bigger studies can explore and asses the effectiveness of the IONM; setting up a precise protocol of use to make this valuable instrument an efficient and safe help for the surgeons who dedicate themselves to neck's dissections.

Author contributions All authors contributed to the study conception and design. "Conceptualization, A.C. and C.B.; methodology, A.C.; validation, C.B. and G.N.; formal analysis, V.S. and E.B.; investigation, L.C.; resources, A.C. and L.C.; data curation, E.B.; writing—original draft preparation, A.C. and V.S.; writing—review and editing, A.C.,V.S. and E.B.; visualization, V.S.; supervision, C.B. and G.N.; project administration, G.N.

Compliance with ethical standards

Conflict of interest The authors declare no competing interests.

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