

RESEARCH PAPER



Facial nerve monitoring in parotid gland surgery: Design and feasibility assessment of a potential standardized technique

Carlos S. Duque¹ | Andrés F. Londoño^{1,2} | Ana M. Duque³ |
Jhon J. Zuleta⁴ | Marcela Marulanda⁵ | Lina M. Otálvaro³ |
Miguel Agudelo⁶ | Juan P. Dueñas⁷ | María F. Palacio⁸ |
Gianlorenzo Dionigi⁹

¹Hospital Pablo Tobón Uribe, Departamento de Cancerología, Medellín, Colombia

²Clínica de Otorrinolaringología de Antioquia "Orlant", Medellín, Colombia

³Sección Otorrinolaringología, Departamento de Cirugía, Facultad de Medicina, Universidad de Antioquia, Medellín, Colombia

⁴Hospital Pablo Tobón Uribe, Dirección Científica, Medellín, Colombia

⁵Sección Cirugía de Cabeza y Cuello, Departamento de Cirugía, Facultad de Medicina, Universidad de Antioquia, Medellín, Colombia

⁶Department of Internal Medicine, Israel Medical Center, Newark, New Jersey, USA

⁷Departamento de Cirugía, Clínica El Rosario El Tesoro, Medellín, Colombia

⁸Sección Cabeza y Cuello, Instituto de Cancerología, Clínica Las Américas - Auna, Medellín, Colombia

⁹Chirurgia Generale, Capitanio Auxiologico, Milan, Italy

Correspondence

Carlos S. Duque, Hospital Pablo Tobón Uribe, Departamento de Cancerología, Medellín, Colombia.
Email: casiduque@hotmail.com

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Abstract

Background: Even though the use of nerve monitoring during parotid gland surgery is not the gold standard to prevent damage to the nerve, it surely offers some advantages over the traditional approach. Different from thyroid surgery, where a series of steps in intraoperative nerve monitoring have been described to confirm not only the integrity but—most importantly—the function of the recurrent laryngeal nerve, in parotid gland surgery, a formal guideline to follow while dissecting the facial nerve has yet to be described.

Methods: A five-year retrospective study was done reviewing the intraoperative records of patients who underwent parotid gland surgery under neural monitoring. The operative findings regarding the neuromonitoring process, particularly in regard to the amplitude of two main branches, were revised. A literature search was done to search for guidelines to follow when a facial nerve loss of signal is encountered.

Results: Fifty-five patients were operated on using the Nim 3 Nerve Monitoring System (Medtronic); 31 were female patients, and 47 patients had benign lesions. Minimum changes were observed in the amplitude records after a comparison was made between the first and the last stimulation. There were only three articles discussing the term loss of signal during parotid gland surgery.

Conclusion: Today, no sufficient attention has been given to the facial nerve monitoring process during parotidectomy. This study proposes a formal guideline to follow during this procedure as well as an instruction to consider when a loss of signal is observed to develop a uniform technique of facial nerve stimulation

KEYWORDS

amplitude, facial nerve, intraoperative neural monitoring, latency, loss of signal, nerve monitoring, parotid gland

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Highlights

- **Question:** Are there reliable guidelines in parotid gland surgery for the use of nerve monitoring to monitor the facial nerve (FN), as there are for thyroid surgery monitoring of the recurrent laryngeal nerve (RLN)?
- **Results:** Even though there are, indeed, some isolated published articles describing the use of nerve monitoring in parotid gland surgery to monitor the FN, none of them are the product of an international effort by recognized surgeons who describe in several publications the formal process of RLN monitoring during thyroid surgery.
- **Comment:** The revision of a five-year experience in parotidectomies done under nerve monitoring prompted a series of questions looking for similarities and disparities in the RLN- and FN-monitoring process, as well as to define whether the protocol for the loss of signal of an RLN could be extrapolated during a similar scenario while dissecting the FN. The same procedure cannot be applied to the loss of signal of the FN or its branches, a detailed proposed guide to approaching this problem is discussed.

INTRODUCTION

Parotid gland surgery entails not only the removal of the tumor but, especially, the preservation of the facial nerve (FN) function, to avoid its most-feared complication, facial paralysis.¹ A surgeon performing parotidectomies must follow a series of classical steps and anatomical landmarks to identify and preserve the main trunk of the nerve and its branches.^{2,3} Intraoperative nerve monitoring (IONM) is not a requirement to perform parotid gland surgery; however, this technology provides the surgeon with a tool that not only allows for faster localization of the nerve but also provides information about its function.^{4–8}

Since 2011, several publications have delineated a series of guidelines and recommendations that must be observed by all thyroid surgeons using nerve monitoring to identify and preserve the integrity and function of the recurrent laryngeal nerve (RLN).^{9–12} There is no doubt that thyroidectomies are performed more than parotidectomies; nevertheless, the devastating effects of an FN injury certainly deserve more dedication and research.^{13–15} Up to the present time, various articles have been published describing—and even denying—the benefits of the use of IONM during a formal parotidectomy, to preserve the function of the FN.^{16–20} However, although some interesting descriptions have been made, only two publications by Kartush et al.²¹ and by Chiang et al.²² delineate an approximation daring to describe a formal guideline to FN stimulation-nomenclature.

A retrospective revision and analysis of a series of parotidectomies performed under IONM were done to describe our experience with the technology, proposing an eventual guide to be followed by surgeons involved in parotid gland surgery under nerve monitoring.

METHODS

A retrospective research proposal was submitted to and approved by the Internal Research Committee of the *Hospital Pablo Tobón Uribe* and *Clínica de Otorrinolaringología de Antioquia (Orlant)* in Medellín, Colombia. The intraoperative records of patients in whom a superficial parotidectomy under neuromonitoring with four channels–electrodes was performed between February 2013 and November 2017 were reviewed. Patients less than 18 years old, and those who had prior parotid gland surgery or a parotid tumor causing facial paralysis were excluded. One of the purposes of the study was to focus on the findings of the intraoperative nerve responses during the intervention. Pre- and post-dissection F₁ and F₂, respectively, electromyographic amplitude (energy represented by a biphasic waveform that represents the ipsilateral vocal cord muscle–fiber activity upon stimuli measured in microvolts–μV) responses upon stimulation recorded throughout the entire procedure were reviewed; the latency (time from the initial stimuli to obtain muscle contraction—measured in milliseconds—ms) numbers for these branches were not considered, as they were incomplete. The Medtronic Nim 3 Nerve Stimulator System (Jacksonville, FL; USA) was used in all cases. At the time of surgery, all patients consented to have their parotidectomy done under IONM. Another important objective of the investigation was to do a 15-year (2006–2021) literature search and review of Pubmed, Google Scholar, and Scopus databases to collect articles containing information regarding the action that a parotid gland surgeon must take if a loss of signal is observed during the FN dissection while performing a parotidectomy. Combinations of terms, such as *facial nerve monitoring* or *neuromonitoring*, *stimulation and/or loss of signal*, *parotidectomy and/or parotid gland surgery*, and *loss of signal*, were used.

RESULTS

During the five-year period of this study, 55 patients were operated on; 31 (56.4%) were females, and the age range was 25–82 years with an average of 50.8 years. Forty-seven (85.5%) patients were operated on due to benign tumors; 30 (54.5%) pleomorphic adenomas; followed by 13 (23.6%) patients with Warthin's tumors and 4 (7.3%) had inflammatory conditions or lipomas; 8 (14.5%) patients were diagnosed with malignant lesions, low- and intermediate-mucoepidermoid carcinomas. All patients were discharged the following day, and a postoperative appointment was scheduled a week later to review the patient's status and pathology report. Table 1 describes the amplitude findings of all parotidectomies done under nerve monitoring; we chose to present the data using the median with its 25th and 75th percentiles for the branches described later on. Along with a low-amplitude response in the final stimulation process F_2 , compared to the initial F_1 response of the inferior branches that was reflected clinically in five (8.9%) of the patients who presented a temporary marginal–mandibular–paresis that recovered completely within 3–4 weeks, transitory, 2-week Frontalis-branch paresis was seen in one patient (1.8%). There were only three articles by (Guntinas-Lichius et al.,⁵ Ozturk et al.,¹⁸ and Kartush et al.²¹) found that briefly mentioned the term *loss of signal* for the FN but without entering into a deeper and enlightened discussion.

DISCUSSION

The classical approach to parotid gland surgery was described more than one hundred years ago; it entails the identification and preservation of the FN, and this technique should not change, regardless of whether the surgeon is using nerve monitoring or not. Even though we are aware of the various described approaches to remove tumors of the parotid gland such as extracapsular removal of limited lesions, partial parotidectomies, and so forth, all our patients were submitted to superficial parotidectomy under neuromonitoring, trying to avoid reinterventions in case that a malignant tumor was described, as many of those patients came from distant and rural areas of the country and the process of procedure authorization is complex, due to the healthcare system. However, if we were considering the use of one of these limited approaches at the time

of the study or in the future, undoubtedly, the use of IONM would be mandatory.^{1,2,23}

Table 2 depicts a series of similarities and disparities between the recurrent laryngeal and FN monitoring processes. The RLN is a branch of the Vagus nerve, though the nerve might also divide itself into at least two or more sensitive ramifications.^{24–27} The FN is a terminal nerve; as the nerve exits through the stylomastoid foramen, it gives origin to the motor and sensory branches (the posterior belly of digastric, stylohyoid, superior auricular, etc.) continued by the main trunk (MT) dividing shortly into a temporozygomatic or superior branch (SB) and a cervicofacial branch or inferior branch (IB), which—at the same time—divides into several tiny motor ramifications as they travel in an external to a medial fashion to innervate the facial musculature.^{28,29}

Even though there is no doubt that technology certainly helps to expedite and look out for the nerve in high-volume lesions, tumors, reinterventions, inflammatory conditions, and so forth, it surely speeds up the process of finding the FN main trunk.^{8,16–20}

Regarding the mechanism of injury to the FN, similar to what has been described for the Vagus or RLN—and since there is not too much experience or published data on the FN trauma under IONM—it can be extrapolated that lesions can be “equally” classified as Type I localized or segmental, affecting only that particular branch that was injured without compromising the other branches, losing that terminal branch response upon stimuli; however, if at the beginning of the procedure—while searching for and dissecting the main trunk—the nerve is accidentally traumatized by section, heat, distension, pressing, and so forth, a Type II global-diffuse lesion will be diagnosed, causing a complete facial paralysis.^{9,10}

It is customary that all of our surgical procedures (thyroidectomies, parotidectomies) performed under IONM are done under a single dosage of *Succinylcholine*, a short-acting and rapid depolarizing muscle relaxant or in some cases using a deep anesthesia technique (*Propofol*), avoiding any type of prolonged muscle relaxation. Even though the use of long-acting neuromuscular blocking agents (LANMBA), such as *Rocuronium*, is an option to intubate the patient, we perform a tap test (gently tapping on the area of the thyroid cartilage–larynx—or the chosen facial muscle, observing a response wave in the monitor due to this stimulation) (thyroid surgery) or the face muscles (parotidectomy) immediately after the intubation, to verify that the tube or the facial electrodes are correctly placed. If a LANMBA is used, the administration of *Sugammadex* will be mandatory at this early step, besides the fact that using this technique in a developing country with limited health resources raises the cost of the procedure. *Succinylcholine* was successfully used in all of our patients without any type of traumatic intubation. After the classical parotidectomy approach is performed and the surgeon's attention is focused on finding the FN main trunk once the tragal pointer landmark is reached, a mapping or “blind” stimulation of the surrounding tissues near the area where the nerve is expected to exit the cranium through the stylomastoid foramina is performed. We have limited this stimulation by using the probe (Medtronic) at no more than 2 mA, even though the system NIM 3 Monitor (Medtronic) can be set from 2 to 3 mA. Once it is set to go beyond 3 mA, the monitor will show a warning that such a higher level of energy may

TABLE 1 Pre- and post-resection amplitude measurements [$M (P_{25}-P_{75})$]

Branch	n	Amplitude (μV)
Pre-Frontalis	56	660.5 (297.0–1216.0)
Post-Frontalis	56	887.0 (326.0–1982.5)
Pre-Mentalis	56	748.0 (439.5–972.5)
Post-Mentalis	56	887.0 (326.5–1932.5)

Note: Superior (Frontalis) and inferior (Mentalis) branches findings

TABLE 2 Similarities and disparities between recurrent laryngeal nerve (thyroid) and facial nerve (parotid) surgery done under intraoperative nerve monitoring

Fact	Thyroidectomy recurrent laryngeal nerve (RLN)	Parotidectomy facial nerve
Is IONM the standard of care?	No, visual identification ²⁴	No, visual identification ^{1,16,17}
Muscle relaxant	Only at the beginning of the procedure	Only at the beginning of the procedure
Endotracheal tube (ET) with electrodes	Two electrodes incorporated into the tube or attached to a conventional tube by a sticker containing the electrodes	No need for a special tube. Four electrodes are used: Frontal, Orbicularis oculi, Orbicularis oris, and Mentalis
Continuous monitoring	Yes, or intermittent ^{12,13}	Although described, not the usual; intermittent ²¹
Principal motor branches	The most anterior, near the trachea ²⁵	All of the branches
Anastomosis between other neural systems or branches	Yes, to the superior laryngeal nerve ^{26,27}	Yes, to the glossopharyngeal nerve or within different ramifications itself ^{28–30}
Number of ramifications	From one to four extra-laryngeal ramifications ^{25,26}	Two main trunks that divide into various branches and subsequently subdivide distally into tiny terminal ramifications ^{28–30}
Blind nerve search—mapping—allows from prompt identification of the nerve	Yes	Yes
Bilateral nerve dissection during a total thyroidectomy	Right and left nerves	Not usual for a patient to have a bilateral parotidectomy at the same surgical setting
Injury to one nerve warns or precludes dissecting the contralateral side; surgery might be ended.	Yes. Each case needs to be studied, but this is certainly a possibility ^{9–12}	No. A different scenario: if a nerve branch is affected or even if the main trunk is damaged, the surgery must be completed.

Note: A detailed description of the process of recurrent laryngeal nerve and FN is shown. Even though both described nerves share some characteristics in all of the anatomical and neuromonitoring processes, there are indeed big differences between them.

potentially harm the nerve. A recent review article by Chiang et al.²² describes their process of stimulation of the FN, starting with 10 mA just as the skin flap is raised; as the tragal pointer is approached, this is lowered to 3–5 mA. This descriptive review article does not involve a series of patients, and it is not clear if they have encountered intra- or postoperative facial muscle palsies in their patients, due to this high-energy delivery. We certainly do not do this type of approach based on the warning delivered by the system itself.^{9,10,22–29,31}

Loss of signal

A loss of signal (LOS) status after trauma to the RLN is determined when these factors are present: a 50% reduction of the original amplitude numbers or a prolongation of the latency; a dramatic drop of the amplitude to 100 μ V, usually meaning a severe trauma that definitively will not stand a chance to recover intra-operatively, along with the absence of ipsilateral contraction of the larynx when the nerve is directly stimulated, and the surgeon's finger is placed under the larynx without sensing any vocal cord mobility (Laryngeal twitch) based on these findings obtained during the stimulation process.^{9,10}

One key factor and advantage to clarify in the neuromonitoring process of the RLN is that if the signal drops more than 50% of its original maximum stimulation data in its amplitude along with a prolongation of the latency time, there is still a chance that the nerve

might recover, depending on the severity of the trauma. The surgeon should decide if—in the presence of such an event—a proven loss of signal that does not improve in a prudent period of time (usually 20–25 min) and in the face of a scheduled total thyroidectomy, the said procedure should be stopped and a completion thyroidectomy done at a later date, waiting for the nerve to recover within the coming weeks while avoiding at that moment the potential risk of a tracheostomy if the contralateral lobe is indeed approached and the nerve is injured. Without a doubt, this is certainly one of the benefits that IONM offers to both the surgeon and the patient.^{9,10,31}

A quite surprising finding of the study was to realize that after exploring the research engines, three articles briefly refer to the process of FN injury and amplitude and latency changes, respectively; however, there is no clear instruction in any of the articles on what to do if a surgeon performing a classical superficial parotidectomy under nerve monitoring is faced with an intraoperative FN loss of signal.^{6,18–21}

Even though there are significant differences in each process of stimulation of the RLN and the FN, a precise directive to advise what action to take if the parotid gland surgeon is faced with a loss of signal has not yet been described. Once the process of FN stimulation is started in the main trunk or in the subsequent branches, surgeons should keep in mind the initial responses of the nerve F₁-pre-dissection amplitude and latency to compare it with the final F₂-post-dissection numbers; however, just as in the RLN monitoring process, at any time the main trunk or particular branch

can be stimulated and compared with the FN1 or a prior one, especially if the surgeon considers that trauma has been inflicted to the nerve.^{20,22}

In our case and based on the analysis of the experience and the data described here, what we do nowadays—in the event that a particular branch has lost its signal, meaning that a considerable difference is encountered in the obtained numbers/nerve stimuli feedback comparing the initial response F_1 once the superior or inferior branches are dissected due to trauma—the surgeon must

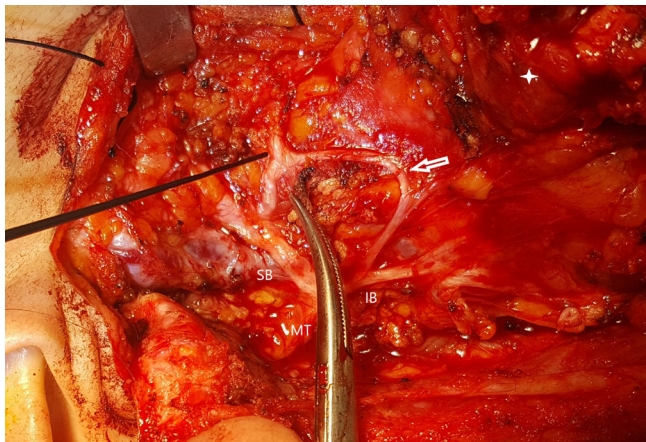


FIGURE 1 Right parotidectomy; the gland with the tumor—star—is about to be removed. Hemostat clamp and the nerve stimulator probe point to a superior branch that communicates with the inferior system depicted by the arrow. IB, inferior branch; MT, main trunk; SB, superior branch.

continue and finish the surgery dissecting the remaining branches. Not only does it seem like the logical thing to do, but also—even if the main trunk is injured at the beginning of the procedure and a dramatic drop in the FN amplitude is observed along with a disturbing prolongation of the latency, which in our patients was not the case (Table 1)—the surgeon will complete the surgery removing the entire gland, avoiding, if possible, any further or severe manipulation of the nerve or its branches. Also, if severe monitoring changes are observed in the nerve pattern for a particular branch, the surgeon might “leave this ramification to rest for a while” and dissect the other branch, giving that ramification a potential chance to recover as has been described for the RLN. Besides, different nerve branches might have a system of interconnecting anastomosis that may “overpass” that trauma area and continue to transmit the stimuli, preserving the harmony to the face (Figure 1).^{28,29,32}

This retrospective study did not have the tools, nor the complete data, to answer the important number to suggest at what point of the amplitude reduction or the prolongation of the latency, a surgeon should consider a true loss of signal during an FN dissection. Undoubtedly, this will require a larger prospective study.

One setback of this series was that the complete information of all four branches/electrodes was incomplete; however, the Frontalis and Mentalis branches, representing the superior and inferior principal branches, respectively, were chosen as the ones with complete and more reliable information, especially regarding the amplitude as detailed in Table 1. In the complete information available, the data collected mostly showed an increase in the numbers obtained for the superior branches; for the marginal mandibular nerve postoperative paresis, a slight decrease in the

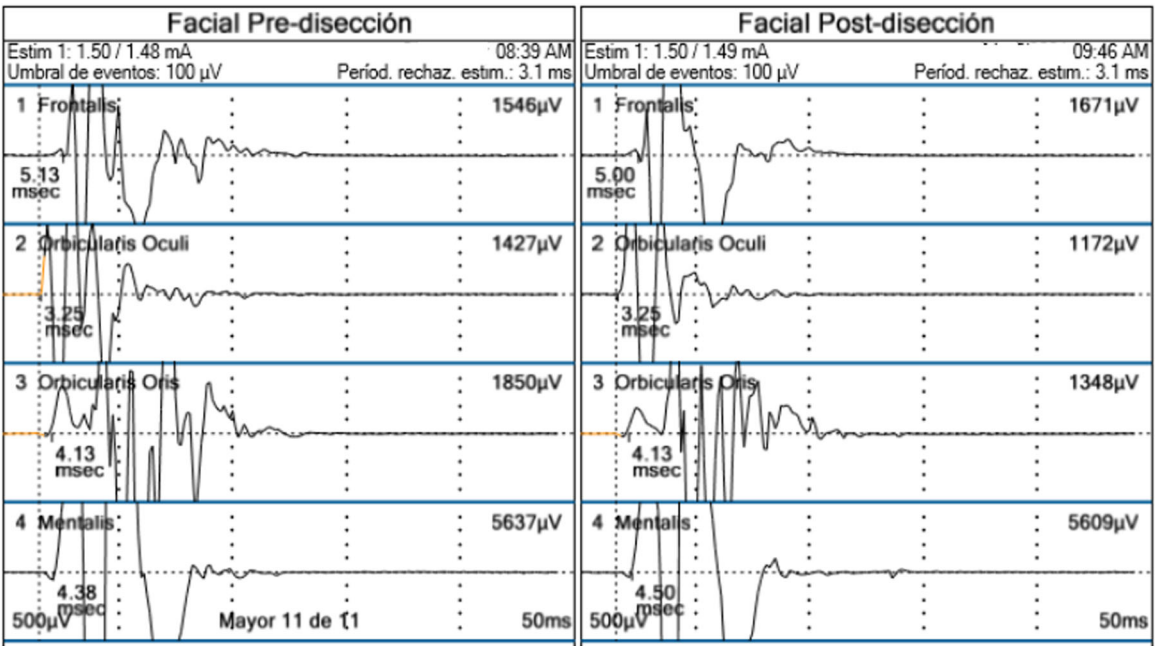


FIGURE 2 Main trunk responses upon stimulation. Predissection done at 1.48 mA, as there is tissue volume covering the different branches; post-dissection is at 1.49 mA while all nerve branches have been dissected, preserved, and exposed. Even though the same electrical stimulus was done at the trunk for illustration-comparison purposes, the postdissection check can definitively be done at a lower energy setting.

amplitude was noticed in five patients who had no permanent problem with their lower lip movement.

In this regard, Table 1 numbers are shown as totals, not individualizing the five patients with marginal mandibular or the patient with Frontalis nerve temporary paresis; those patients with impaired movement recovered within a month or so. In spite of that, as it is noticed in Image 3 taken from a patient in a similar scenario, there is a significant drop in the amplitude values for the Orbicularis Oris, from 924 to 308 μ V; nevertheless, the latency remained the same, at 3.88 ms. Even though this particular patient did not have a temporary postoperative paresis, if such an event had occurred, it should have been limited as the patients described in the study. It is important to mention that a surgeon does not always obtain a similar "desired" amplitude at the end of the procedure; this occurs sometimes as the stimulation probe is not correctly placed on the nerve branch, it is covered by soft tissue or blood, or it is pointed to nearby tissues deriving in lower conduction and response. This problem can be solved by repeating the stimulus on the nerve and cleaning the area, especially if the surgeon is sure that no trauma was inflicted on the nerve (Figures 2 and 3).

Our results prompted us to recognize, analyze, and revise our strategy for every parotidectomy done under IONM in our department, proposing an initial guideline to follow, as shown in Table 3. It is worth stimulating the main trunk at the beginning of the procedure, observing, and saving the result of the four targeted muscle zones with their amplitude and latency responses in the monitor and comparing them to the following ones. If a surgeon wants to be more precise on the final integrity and functionality of the nerve, feedback from the superior and inferior branches or any particular branch might also be obtained if they were individually stimulated and saved early in the case.

Different from the established and accepted guidelines for RLN neuromonitoring, there is not yet a multidisciplinary effort from parotid-gland surgeons around the world to describe a given number to call a loss of signal during the FN monitoring process. An adaptation of the process learned from the RLN practice guides is useful, and it should be taken as a starting point for future reference building of individualized FN monitoring guidelines based on the experience gained and the few articles published so far in this matter.^{9,10,21,22}

Indeed, even though more prospective studies are needed, this is a lengthy process of building a guideline for FN monitoring during parotid gland surgery that is not only accepted by most surgeons but also offers practical and reliable information, thus ensuring the same protocol is used for each patient.

CONCLUSION

Without a doubt, the early analysis of the data allowed us to correct many aspects of the FN stimulation process during our parotidectomies.

Even though there are no definitive guidelines to follow yet in parotid gland surgery and FN preservation, as there are in thyroid

surgery, this review will hopefully be followed by a prospective study that includes all four muscles systems to continue giving support to the use of the neuromonitoring experience in this procedure.

AUTHOR CONTRIBUTION

All authors participated in the study design development and final description; however, the following distribution of tasks was assigned to different authors to obtain the most of their knowledge and expertise. At the end of the document, all authors approved the article, once they have revised the draft, tables, and images and had given their input on it, and corrected or suggest changes along the document. Initial distribution of document development was distributed as follows: **Carlos S. Duque** and **Andrés F. Londoño**: Leading surgeons, and data providers involved as well in the entire document build-up and analysis. **Marcela Marulanda**, **Lina Otálvaro**, **María F. Palacio**, and **Miguel Agudelo**: Data clearing and revision. Table construction, literature search, and comparisons. **Ana M. Duque** and **Jhon J. Zuleta**: Data recollection, analysis, and presentation. **Juan P. Dueñas** and **Gianlorenzo Dionigi**: Neuromonitoring expertise advice, regarding thyroid surgery under nerve monitoring, analysis, and presentation of data.

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CONFLICT OF INTEREST

Drs. Carlos S. Duque and Juan P. Dueñas teach courses in neuromonitoring techniques in head and neck surgery to surgeons in Latin America with the sponsorship of Medtronic and had been receiving honoraria from the activity. Dr. Gianlorenzo Dionigi receives an honorarium from Medtronic and Innomed. The remaining authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author, Carlos S. Duque, it has also been sent to the Journal to support the main text submission process, and it rests in their files. It is an Excel form datasheet. ID and names have been removed to guard patient privacy and confidentiality.

ETHICS STATEMENT

The study was approved by both institutions, all patients consented to have their parotid gland surgery under nerve monitoring.

ORCID

Carlos S. Duque  <http://orcid.org/0000-0002-0289-0399>

Andrés F. Londoño  <http://orcid.org/0000-0002-1996-1122>

Ana M. Duque  <http://orcid.org/0000-0002-2830-0801>

Jhon J. Zuleta  <http://orcid.org/0000-0001-5407-7714>

Marcela Marulanda  <http://orcid.org/0000-0002-5927-7923>

Lina M. Otálvaro  <http://orcid.org/0000-0002-7907-4365>

Miguel Agudelo  <http://orcid.org/0000-0002-6424-1896>

Juan P. Dueñas  <http://orcid.org/0000-0002-7206-9037>

María F. Palacio  <http://orcid.org/0000-0001-5601-3204>

Gianlorenzo Dionigi  <http://orcid.org/0000-0003-0864-6087>

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