Original Article

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Monitoring the Laryngeal Nerves During Thyroidectomy. Initial 115 Cases Experience

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Rezumat

Monitorizarea nervilor recurenți în cursul tiroidectomiei. Experiența primelor 115 cazuri

Leziunile nervilor recurenți constituie, în ciuda incidenței scăzute, una dintre cele mai severe complicații post-tiroidectomie. Disecția atentă intraoperatorie a nervului recurent (RLN) este considerată „golden standard" în prevenirea leziunilor acestuia. Studiul evaluează reperele tradiționale utilizate în identificarea vizuală a nervului recurent precum și situațiile de risc chirurgical crescut. Este prezentată experiența noastră inițială utilizând neuromonitorizarea intraoperatorie a nervului recurent în cursul tiroidectomiei. Rezultatele obținute evidențiază că tuberculul Zuckerkandl (TZ), atunci cand este identificat (72,97%), constituie un important reper anatomic, nervul situându-se în 95,06% dintre cazuri pe fața posterioară a TZ. Dintre situațiile cu risc crescut de leziune am identificat 2 nervi cu traseu nerecurent. Ramificarea extralaringiană a fost întâlnită în 23,8% dintre cazuri, mai frecvent între artera tiroidiană inferioară și intrarea în laringe (86,04%). Monitorizarea ramurilor RLN la o intensitate a curentului de stimulare de 0,5 sau 1 mA evidențiază semnal electromiografic (EMG) predominant pe ramura anterioară ceea ce subliniază importanța identificării și prezervării acesteia în chirurgia tiroidiană. Dintre cei 222 RLN monitorizati am obținut semnal EMG în 215 cazuri (96,84%). Atunci când nu s-a obținut semnal, principala cauză a fost reprezentată de poziționarea deficitară sau dezlipirea de pe sondă a electrodului laringian. Neuromonitorizarea intraoperatorie (IONM) a RLN este o procedură cu implementare facilă și o curbă de învățare scurtă. IONM este sigură pentru pacient și utilă în localizarea nervului precum și în confirmarea integrității sale la sfârșitul intervenției. Evaluarea eficienței IONM în prevenirea leziunilor recurențiale necesită studii mai extinse.

Cuvinte cheie: nerv laringeu recurent (RLN), tuberculul Zuckerkandl (TZ), neuromonitorizare intraoperatorie (IONM)

Abstract

The lesions of the laryngeal nerves, despite low incidence, are the most severe long term complications after thyroidectomy. Visualization after careful dissection of the recurrent laryngeal nerve (RLN) is now the golden standard among thyroid surgeons. We assessed traditional landmarks for the identification of RLN and anatomic high risk situation. The study also presented our initial experience using neuromonitoring of RLN (IONM) during surgery. The results show a recognizable Zuckerkandl tubercle in 162 of the 222 cases (72,97%). After dissection RLN was found posterior from TZ in 154 cases (95,06%) and lateral from TZ in 8 cases (4,93%). The identification of the Zuckerkandl tubercle is a useful landmark for RLN localization. As concerning high risk situations we found 2 non recurrent laryngeal nerves (both on the right side). Extra laryngeal ramification of RLN is an anatomical reality with significant incidence (23,8% in our study) and major surgical involve-

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ment. Extra laryngeal ramification of RLN occurs more often between the cross point with inferior thyroid artery and larynx entry point. Monitoring the branches of RLN we obtain major EMG signal on the anterior one. The surgical meaning is that the anterior branch carries the most important motor fibers and we have to pay extra care in the correct identification and preservation of it. From a total of 222 visually identified RLN we have 215 nerves (96,84%) with positive EMG signal on monitoring. For 7 nerves (3,15%) we had no EMG signal. In 3 cases (2 total thyroidectomies and 1 lobectomy) involving 5 RLN there was a false negative result caused by electrode malposition or desoldering from endotracheal tube. Our initial experience shows that IONM is harmless, easy to handle and a useful tool for identifying the nerve and confirm its integrity. More extended studies are needed to show if intraoperative monitoring decreases the rate of RLN iatrogenic injury.

Key words: recurrent laryngeal nerve (RLN), tubercle of Zuckerkandl (TZ), intraoperative neuromonitoring (IONM)

Introduction

Despite low incidence (0,5-1%) lesions of the laryngeal nerves are the most severe complications after thyroidectomy. In the last decades the great majority of thyroid interventions are total thyroidectomies or total lobectomies. Those types of interventions involve a higher risk for recurrent nerves (RLN) compared to subtotal thyroidectomy. Visual identification of RLN during surgery is considered golden standard for preserving the integrity of the nerves, lowering the incidence of injury from 5% to less than 1%. However, even if laryngoscopy shows no modifications of vocal folds, some patients complain of important voice modifications. Recent studies (15) consider that 87% of the patients show voice modifications three weeks after total thyroidectomy and 15% present major voice problems six months after surgery (16). 6% of the patients appreciate that the quality of life decreases after thyroidectomy. It is interesting to notice that only a small part of these patients have real vocal fold paralysis during laryngoscopy. Some patients having laryngeal nerve injury could became asymptomatic due to compensatory vocal fold behavior. Most of the patients improve spontaneously following the reinervation process. Recovery takes place usually in the first 3 months. 6 months after the onset of paralysis most patients recover sufficiently to avoid surgical treatment. (12) The recovery rarely takes place after one year from injury. It is well-know that in case of partial injury or neuropraxia of RLN, laryngoscopy shows no modification despite obvious change of voice. In that case videofibroscopy associated with stroboscopy may highlight signs of partial denervation of the vocal folds. Laryngeal electromyography (LEMG) is the most objective method to evaluate the function of the nerves and muscles of the larynx. If the nerve is affected by neuropraxia or its function is partially recovered, LEMG shows normal potentials even if their number is reduced. LEMG is useful for diagnosis at patients with mild paresis on endoscopic examination. Sometimes LEMG demonstrates bilateral paresis at patients with normal endoscopic examination. LEMG is used for prognosis purposes at patients with RLN injury but only in the first 6 months after injury (1,12). After this period LEMG has no prognosis value. The lesion of the external branch of the superior laryngeal nerve (SLN) leads to less important voice modifications. In SLN paralysis a loss of head register and reduction of voice bellow one octave can be observed (normal voice has two octaves). However, these modifications are significant for singers and professional speakers. That's why SLN modifications are less frequently evaluated in postoperative period ("the neglected nerve" during thyroidectomy). (2,12)

Dissection of the RLN is essential for preventing injuries. However, even in the hands of an experienced surgeon the lesions may occur sometimes even when nerve monitoring is used during surgery (2). Inexperienced surgeons are an important independent risk factor (1). Other pathological risk factors for recurrent laryngeal nerve injuries are: total thyroidectomy, voluminous goiter and thyroid cancer. Temporary paresis after thyroidectomy ranges between 1 - 6%, while permanent paralyses are between 0.05 – 2.5%. For patients undergoing thyroidectomy for cancer, temporary RLN injury is 0.7 - 4% and permanent paralysis 1.6 - 10%. Reintervention has a high risk of injury. RLN paresis occurs in 10% of cases while permanent lesions are reported in up to 8% of patients. (13)

Another risk situation is the distortion of usual anatomy. (14) The presence of non recurrent laryngeal nerve increases the risk of injury up to 12,9%. Extra laryngeal ramification of RLN is not rare (between 19 to 56% according to different authors) (3-7). In these situations, when the nerve is seen, it could be just the posterior branch in a lower ramification. The anterior branch carrying the most important motor fibers is stuck in the posterior side of the thyroid lobe and may be easily injured. (12)

Medico legal implications of RLN injury are important. Sometimes a unilateral nerve damage may be overlooked due to compensatory behavior of the larynx muscle, especially if the patient is not a vocal professional. On the other hand a bilateral lesion could become a drama for both patient and his surgeon. 30% to 50% of endocrine malpractice litigation involves thyroid and parathyroid surgery. 70% to 90% of these are due to RLN injury with bilateral paresis accounting for nearly 30% of cases. Only one of three judgments is in favor of the defendant. (12,13)

In an era of evidence based medicine, surgeons search for the support of an objective method to confirm the integrity of RLN during surgery. The first use of technology in an attempt to reduce the risk to the RLN was published in 1965 (13). Using prior experience with intraoperative stimulation of the facial nerve during parotidectomy, the authors try to stimulate RLN and recording a physiological response. Unfortunately, unlike the facial nerve, RLN requires the use of an indirect means of monitoring. Early technology using balloon pressure transducer or pneumatic spirography showed some results but

did not gain much of a support and were abandoned. The development of the laryngeal mask airway in the early '80 encouraged the surgeons to observe the response to RLN stimulation by direct view of the vocal folds during surgery. Many surgeons continue to use them today. Unfortunately, this method has some major disadvantages: the necessity of additional instrumentation and equipment in the operation room, trained personal for using laryngoscopy during surgery, the potential loss of control of the airways using laryngeal mask. Since the 1950's and the 1960's numerous authors experimented with EMG of the laryngeal muscles to evaluate their activity during respiration and phonation. Flisberg and Lindholm were the first to study the electrophysiology of RLN during major neck surgery bringing this technique in the operation room. In 1996 Davis and Eisele introduced the laryngeal surface electrode (14). The electrode is applied on endotracheal tubes and allows continuous intraoperative assessment of the vocal folds function. The implication of commercial firms in those studies and the development of adhesive stitch electrode (Hemmerling, 2001) has spread the intraoperative nerve monitoring (IONM) technique all over the world.

Material and Methods

Our study was carried out on 123 cases during a period of 16 months, between January 2014 to April 2015. We have an 8 years experience in thyroid surgery, performing 487 thyroidectomies. Operations were made by the same medium volume surgeon (80-96 thyroidectomies/year) with visual identification of RLN. The most common procedures were total thyroidectomies/lobectomies (over 97.8 %). Since December 2013 we have started monitoring RLN using a Neurosign 100 device (*Fig. 1*) produced by Magstim (U.K.). There is no financial or professional association between the authors and the commercial company whose nerve monitoring product was used. 8 cases were replaced from the study because the device or supplies were temporary unavailable. For the remaining lot of 115 patients we analyzed the structure in terms of sex, age, background, diagnosis, types of operations and results of histology. The data were recorded according to observation sheets, operation data, pathological results and specific questionnaires. We review the relations of RLN with its traditional landmarks: inferior thyroid artery, esotracheal groove and especially Zuckerkandl tubercle (TZ). The Zuckerkandl tubercle is an embryological remnant of the primordial thyroid that is present in 60% to 90% of adult glands. Pelizzo in 1998 was first to show the importance of TZ as landmark for the RLN dissection (8). Pelizzo's classification of TZ has 4 degrees: 0 degree when TZ is absent, first degree when the tubercle is less than 5 mm, second degree when it is between 5mm and 1 cm, third degree when it is bigger than 1 cm. (8) Yalçin thinks that the size of the tubercle is not so important and proposes the term of recognizable tubercle for second and third degree of Pelizzo's classification (9-11). TZ is mostly placed in the medium third of thyroid lobe (82.8%); however it can be found in the lower part (12%) or the superior one (5.2%) (10). TZ shows RLN or his branches like an arrow pointed to the nerve.

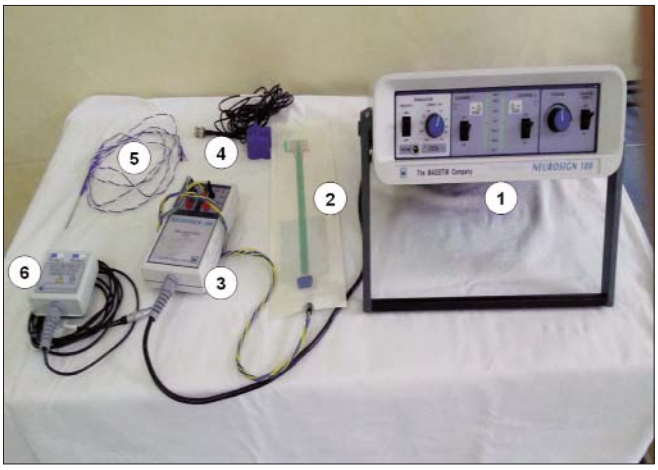

Figure 1. *Neurosign 100 ENT stimulator includes: stimulator module (1), endotracheal electrodes (2), preamplifier (3), mute sensor (4), bipolar concentric stimulator probes (5), stimulator probe pod (6) (14)*

High risk anatomic situations like non recurrent laryngeal nerve and RLN extra laryngeal branches were evaluated.

The IONM technique was used according to literature data and producer' recommendations. At the beginning of the procedure, the laryngeal electrode (*Fig. 1 no. 2*) is stuck to the endotracheal tube using the landmarks proposed by the producer.

The correct position of endotracheal tube has to be checked by laryngoscopy because malposition of endotracheal tube is the main cause of monitor dysfunction. If the tube is too deep or too shallow, it needs to be replaced or rotated to allow the sensor to be in contact with vocal folds. After intubation it is strongly recommended not to modify the patient's neutral position. The induction of anesthesia is usually made with fentanyl. Laryngeal muscle contraction is not possible if neuromuscular block is used. IONM cannot function if the patient is paralyzed. There are three levels of stimulation: vagal stimulation, RLN localization and RLN identification. (14)

Vagal stimulation is useful for confirming that the monitor works and to ensure the normal pathway of the RLN before surgery. After the mobilization of the superior pole and the ligation of the small inferior veins, the thyroid lobe is retracted medially. We open the space between the thyroid gland and carotid sheath and identify the vagus nerve. The stimulation takes place in the midneck region using a current of 2mA and evoked EMG signals are defined as V1 signals. (14) Vagal stimulation is not mandatory. We only used it when thyroidectomy is associated with cervical lymphadenectomy and we obtained a positive EMG response. In one case of voluminous thyroid lymphoma invading RLN, esophagus and jugular vein we have to resect deliberately the RLN that was embedded in the tumor. In that case we had no EMG response at vagal stimulation confirming nerve injury during surgery. This aspect is of particular importance. If we have a confirmed unilateral lesion by IONM, we can change operation plans for the other lobe allowing to avoid bilateral lesions. This modification in

operation management is an important advantage of IONM. In our case unilateral vocal fold paresis was confirmed by laryngoscopy.

RLN localization is practiced after opening the space between the thyroid gland and carotid sheath. The nerve is searched at the level of tracheoesophageal groove. If the Zuckerkandl tubercle is recognizable we use its area with a "searching current" of 1-2 mA. If the stimulation current fail to localize the nerve we can increase intensity to 3 mA. Following this search parameters, the nerve could be stimulated from a distance of 1,5 cm. In case of two structures running together (anterior and posterior branches of RLN, or a small artery and RLN), a false EMG signal can be induced by shunt stimulus (21). In these cases, we have to lower the stimulation level to 0,5 mA if we want to differentiate a motor branch from a sensory branch or a small artery from RLN. The EMG signals obtained from RLN localization are defined as L signals.

After RLN was localized and identified, it can be stimulated for definite confirmation. The intensity of current stimulation ranges between 0.3 to 1 mA, without significant difference between the magnitudes of EMG amplitude obtained by stimulation. We usually used a bipolar concentric probe for RLN localization and a monopolar probe for confirmation after dissection. The EMG signals obtained from direct RLN stimulation are defined as R1 signals.

Results

The study involves 123 patients with thyroid disease hospitalized in our department during a period of 16 months. Of these 123 patients there were 103 women and 12 men, resulting a sex ratio F/M= 8,58/1. The average age was 55 years (ranged between 16-74 years old). More frequently patients were in the 6th or 7th decade of life (33,3 and 24,3%). According to histology the diagnosis of thyroid disease was: nodular goiter 92 cases (72,79%), Graves disease 5 cases (4,06%), toxic adenoma 6 cases (4,87%), thyroiditis 6 cases (4,87%), recurrent goiter 2 cases (2,43%), thyroid lymphoma 1 case (0,81%), papillary carcinoma 13 cases (10,56%). We practiced 100 total extracapsular thyroidectomies (86,5%), total lobectomies 8 cases (6,95%), reoperations 2 cases (1,73%), total thyroidectomies with cervical lymphadenectomy 5 cases (4,34%).

8 cases were replaced from the study because the device or supplies were temporary unavailable. From the remaining 115 cases we visually identified 222 RLN (8 cases of lobectomies). According to Yalçin's classification we find a recognizable Zuckerkandl tubercle in 162 out of 222 cases (72,97%). After dissection RLN was found posterior from TZ in 154 cases (95,06%) and lateral from TZ in 8 cases (4,93%). If it can be identified, the Zuckerkandl tubercle is a useful landmark for RLN localization. On the other hand, inferior thyroid artery which has been regarded as a traditional landmark for RLN has not proved in our study to have a constant relation with the nerve. There were significant differences not only among patients but also in both sides of the same patient especially if we had RLN extra laryngeal ramifications. The relationship between RLN and esotracheal groove were similar to those reported in the literature.

Concerning high risk situations, we found 2 non recurrent laryngeal nerves (both on the right side); one type 1 - emerging high from vagus and the other type 2A - emerging from the vagus in the middle neck section.

From a total of 222 RLN we found a common trunk in 169 cases (86,2%) and extra laryngeal ramifications on 53 nerves representing 23,8%. 51 RLN had 2 branches and 2 RLN had 3 branches. Considering inferior thyroid artery (ATI) and RLN larynx entry point as landmarks, ramification occurs at the level of ATI in 19 cases (35,4%), post arterial in 24 cases (45,3%), prelaryngeal in 6 cases (11,32%), prearterial in 4 cases (7,54%). The extralaryngeal ramification takes place in 45 cases (86,04%) in the last 10 mm from the larynx entry point.

From a total of 222 RLN visual identified we have 215 nerves (96,84%) with positive EMG signal on monitoring. For 7 nerves (3,15%) we have no EMG signal. In 3 cases (2 total thyroidectomies and 1 lobectomy) involving 5 RLN there was a false negative result caused by electrode malposition or desoldering from endotracheal tube. In 2 cases the RLN was injured during surgery: in one case deliberately, due to tumor invasion and in one case accidentally. In this situation the anterior branch in a low (prearterial) ramification of RLN was cut. After injury we had no EMG signal and laryngoscopy confirmed vocal fold paralysis.

In case of RLN extra laryngeal ramification we monitored the branches distinctively. For this purpose we had to decrease current intensity to 1 or even 0,5 mA to avoid shunt stimulus. The EMG amplitude signal was different on the anterior branch as compared to the posterior one. On the anterior branch the signal amplitude ranges between 1 to 20 mV and in the posterior branch the EMG signal is very low, between 0 to 30 μV. (*Figs. 2* and *3*)

If we decrease the current intensity the difference becomes more obvious. This observation is not singular. Previous studies highlight that there are huge differences between branches in terms of conducting the EMG signal. There are two explanations: the motor fibers of RLN are placed prevailing on the anterior branch of RLN or the anterior branch carrying the motor fibers for the most important laryngeal muscle, the posterior cricoarytenoid. Anyway, from a surgical point of view it is very important to preserve the anterior branch of RLN especially because it is more frequently exposed to injury.

The mortality in our study was 0%. There was one case of cervical hematoma which had to be evacuated by surgery and 5 cases of transient hypoparathyroidism. In both cases of RLN injury laryngoscopy confirmed vocal fold paralysis. Dysphonia was present in the first 3 months but improved afterwards. There was no bilateral RLN lesion.

Discussions

Visual identification of RLN during total thyroidectomy is essential to prevent lesions. In our study recognizable Zuckerkandl tubercle proves to be a reliable landmark for RLN. When we can identify TZ the nerve is almost always beneath it (95,06%). Unfortunately TZ is not identifiable

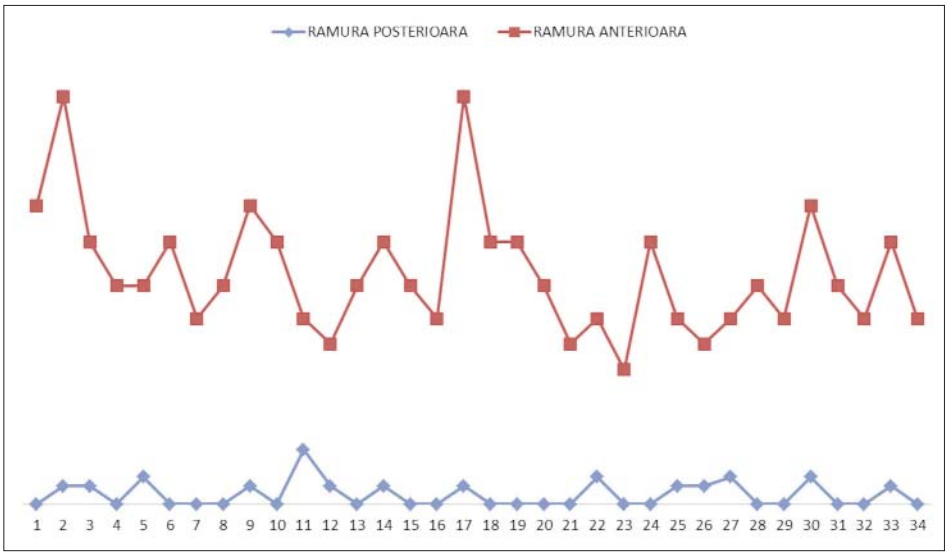

Figure 2. *EMG signal amplitude on the anterior RLN branch ("superior line) vs posterior branch (inferior line). Current intensity 1 mA*

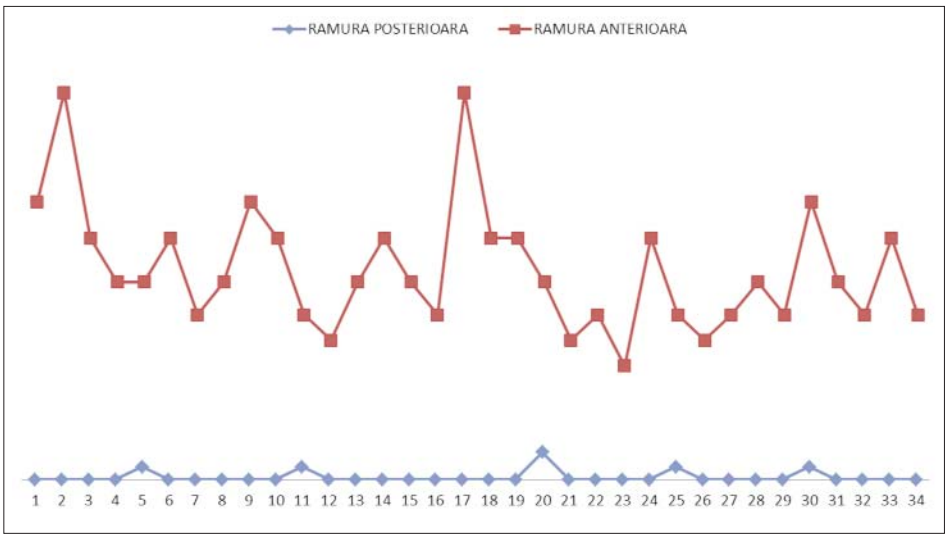

Figure 3. *EMG signal amplitude on the anterior RLN branch ("superior line) vs posterior branch (inferior line). Current intensity 0,5 mA*

every time. There are two reasons for this: first of all TZ is sometimes (28% in our study) too small, under 5 mm (0 and 1 degree from Pelizzo' classification). On the other hand, in case of multinodular goiter with nodules placed on the posterior side, it is difficult to distinguish between TZ and a "normal" goiter nodule. In this case we use IONM to localize the nerve and after that we identify the Zuckerkandl tubercle above it.

Extra laryngeal ramification of RLN is an anatomical reality with significant incidence (23,8% in our study) and major surgical involvement. Embranchment occurs more often between the cross point with inferior thyroid artery and larynx entry point. If the nerve is too thin it could be just a posterior branch in a lower ramification. The anterior branch could be stuck on the thyroid lobe and easily injured, like it happened in our case.

It is important to notice that by monitoring the branches of RLN we obtain major EMG signal on the anterior one. The surgical meaning is that the anterior branch is carrying the most important motor fibers and we have to pay extra care in the correct identification and preservation of it.

IONM is a useful tool for identifying the nerve and confirming its integrity. Visual identification does not necessarily mean functional integrity. By obtaining a vocal fold response, IONM provides confirmation that the anatomically preserved nerve is also electrophysiologically intact. IONM is harmless and easy to use. In our experience, after the initial learning curve, IONM does not extend operation time but additional setup time at the beginning of surgery is needed. The major disadvantage is represented by the rise of operation costs due to monitoring equipment and especially the supplies (laryngeal electrodes and stimulation probes).

The essential question regarding the use of a monitor during thyroidectomy is: can intraoperative monitoring improve a procedure with an already low rate of reported iatrogenic injury? The answer to this question is controversial and continues to be debated. The present study does not intend to give an answer and cannot offer one. There are three reasons for this: first of all it is an initial study and the results could be

altered by the learning curve. On the other hand, the number of RLN included (222) is too small. Thanks to the low injury rate (with or without nerve monitoring) the statistical analyses show that it has to be more than 1000 RLN at risk to obtain statistically significant results. Last but not least we practice pre and post operative laryngoscopy only in symptomatic cases. For the correct assessment of RLN injuries routine pre and post operative laryngoscopy associated with stroboscopy is mandatory.

Conclusions

1. Recognizable Zuckerkandl tubercle is a reliable landmark for RLN visual identification during thyroidectomy.
2. Extra laryngeal ramification of RLN is an anatomical reality with significant incidence and major surgical involvement. Monitoring the branches of RLN we obtain major EMG signal on the anterior one.
3. Our initial experience shows that IONM is harmless, easy to handle and a useful tool for identifying the nerve and confirm its integrity.
4. More extended studies are needed to show if intraoperative monitoring decreases the rate of RLN iatrogenic injury.

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