LITERATURE REVIEW

Neuromonitoring the laryngeal nerves during thyroidectomy – literature review and initial experience

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ABSTRACT

Visual identification of the recurrent laryngeal nerve (RLN) is the standard procedure among thyroid surgeons. However, nerve lesions still occur due especially to some particular anatomic or pathological situations. Intraoperative nerve monitoring (IONM) is a useful tool to identify nerves, to provide feedback during dissection and to confirm the functional integrity of RLN at the end of the procedure. IONM has a high specificity and negative predictive value, but sensitivity and positive predictive value are low. Even though the role of IONM in decreasing RLN paresis / paralysis is controversial, most of the authors consider IONM useful, especially in difficult cases. We present our initial experience using IONM of RLN during thyroidectomy.

KEYWORDS: Intraoperative nerve monitoring (IONM), recurrent laryngeal nerve (RLN), electromyography (EMG)

INTRODUCTION

Lesions of the laryngeal nerves are, despite low incidence (0.5-1.5 %), one of the most severe complications after thyroidectomy. Visual identification during surgery is considered the golden standard for preserving the integrity of the nerves, lowering the incidence of injury from 5% to less than 1%. However, in some particular situations, the risk of nerve damage remains considerable: non-recurrent laryngeal nerves (12.9%)[1], reoperations for benign goiters (8.1%) and thyroid carcinomas (up to 10.6%)[2]. Another risk situation is when the nerves divide in branches before entering the larynx[3]. When the nerve is seen, it could be just the posterior branch in a lower ramification. The anterior branch carrying the most important motor fibres is stuck in the posterior side of the thyroid lobe and may be easily injured[4].

Anatomy may be distorted in case of revision surgery, following radiation therapy, in large goiters, inflammatory process or carcinomas. In these cases, the usual anatomic landmarks may not be recognised and visual identification of the nerves becomes very difficult. During total thyroidectomy, it is reported an incidence of failure to find the nerves in 5-18% of cases[5].

Miller and Spiegel[2] consider: "There are a lot of reasons explaining why, even in the hands of a skilful and knowledgeable surgeon, iatrogenic RLN injury does indeed occur."

Visually identifying the recurrent laryngeal or vagus nerves during thyroid and parathyroid surgery can be difficult in areas with poor visibility, even with a detailed knowledge of anatomy and surgical skill. Studies[6-8] indicate that intraoperative nerve monitoring (IONM) of the recurrent laryngeal nerve is recommended as a risk-minimizing tool.

IONM is using a low intensity current to stimulate RLN or the surrounding tissue. IONM confirms the integrity of RLN before and after thyroidectomy. A laryngeal surface electrode is applied on the endotra-

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cheal tube in contact with the vocal folds. The current produced by the stimulating probe at the level of the vagus nerve of RLN determines movements of the laryngeal muscle. The laryngeal electrode sends the electromyographic (EMG) signal to the front panel and a specific sound confirms the nerve integrity. Modern monitoring devices may be used to identify nerves from surrounding tissues, to provide feedback during dissection or confirm the integrity of a dissected nerve. An EMG monitor may be attached to record specific EMG signals.

HISTORY

At the beginning of the 70's, Flisberg and Lindholm were the first to study the electrophysiology of RLN during major neck surgery[9]. Riddle[7], on his experience including over 1700 thyroidectomies, described a subpopulation of 122 patients in whom RLN not only was identified, but also electrically stimulated. In 1992, Rice and Cone-Wesson followed by Beck and Mayers started to investigate clinical applications for nerve integrity monitor (NIM)[9]. In 1996, Davis and Eisele introduced the laryngeal surface electrode. The electrode is applied on endotracheal tubes and allows continuous intraoperative assessment of the vocal folds function[9,10]. In 2001, Hemmerling proposed an adhesive stitch electrode to apply over the orotracheal tube[9]. Since 2002 Rendolf has spread the IONM technique all over the world[11].

IONM TECHNIQUE

At the beginning of the procedure, the laryngeal electrode is stitched to the endotracheal tube using the landmarks proposed by the producer. The correct position of the endotracheal tube has to be checked by laryngoscopy. Some studies[12] reported that malposition of EMG endotracheal tube was the main cause of monitor dysfunction. If the tube position is too deep or too shallow, it needs to be replaced or rotated to allow sensor contact with the vocal folds. The endotracheal tube misplacement is the main cause of false positive results[13].

The patient's head and neck are kept in neutral position during tracheal intubation. It is strongly recommended not to modify the patient's position after intubation. The induction of anaesthesia is usually made with fentanyl. Laryngeal muscle contractions are only possible if limited or no neuromuscular block is used. IONM cannot function if the patient is paralysed. If small quantities of neuromuscular blocking drugs are used, we have to change the current frequency from 3 to 30 Hz.

Procedures for RLN localization and identification include three levels of stimulation: vagal stimulation, RLN localization and RLN identification. A bipolar concentric probe is regularly used for RLN localization because it allows stimulation through surrounding tissue. For direct stimulation of the vagus nerve or RLN, a monopolar probe can be used.

Vagal stimulation

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 the carotid sheath and identify the vagus nerve, which is tested to insure the monitoring system works and to confirm the functional integrity of RLN at the beginning of operation. The vagus nerve is usually stimulated in the midneck region with a current of 2mA and the evoked EMG signals are defined as V1 signals. Dralle[14] considers that the vagal stimulation has to be the golden standard for IONM procedure. Vagal stimulation before RLN localization is a necessary step to confirm that the monitoring system is working, to ensure the normal pathway of the RMN and to provide reference data for the EMG signal[15].

RLN localization

After opening the space between the thyroid gland and the carotid sheath, the position of RLN is localized with a bipolar concentric stimulating probe at the level of the tracheoesophageal groove. For evoked EMG, an initial "searching current" is delivered at an intensity of 1mA (after Parmeggiani)[9] or 2mA (after Chiang)[12]. If the stimulation current failed to localize RLN, we can increase the current intensity to 3mA[12]. Following these searching parameters, the nerve could be stimulated from a distance of 1.5 cm[9]. In case of two structures running close together (anterior and posterior branches of the RLN, or a small artery and RLN)[16], a false EMG signal can be induced by a shunt stimulus. In these cases, we have to lower the stimulation level to 0.5mA if we want to differentiate a motor branch from a sensory branch or a small artery from the RLN[11]. Some authors[5,13,17] strongly recommend that RLN should be localized and identified with IONM at the level of the inferior thyroid artery and not only at the level of Berry's ligament. Advantages of early identification of RLN with IONM are: 1. Stretch injury caused by excessive traction of the thyroid can be avoided; 2. Extralaryngeal branches of the RLN, typically anterior and posterior branches, can be identified; 3. The inferior parathyroid gland can be visualized and preserved[12,15].

The EMG signals obtained from RLN localization are defined as L signals.

RLN identification and dissection

After the RLN was localized and identified, it can be stimulated for definite confirmation. The intensity of current stimulation ranges between 0.3 to 1mA, without significant difference between the magnitudes of EMG amplitude obtained by stimulation. The nerve is dissected from the level of inferior thyroid artery to the entry of the larynx. The EMG signals obtained from direct RLN stimulation are defined as R1 signals.

The studies[12,15] show that the signal obtained from RMN localization (L signal) is a clear and reliable EMG response that is similar to that from direct vagus (V1) or RLN (R1) stimulation; the mean amplitude of each signal (V1, L and R1 signals) is 811±389µV, 932±436µV and, respectively, 1,132±472µV.

ADVANTAGES AND DISADVANTAGES OF IONM

Advantages:

- IONM is an atraumatic procedure. No adverse events resulting from using of IONM were reported in the studies. There is a theoretical risk of inducing paresis by repeatedly stimulating the RLN, but it was never objectively proved.
- It is easy to use. Parmegiani and colleagues[6] show that they needed two months to learn the new methodology and the first 50 cases were not taken into account because of the procedure, interpretation of signal and other technical problems and, of course, the learning curve.
- Continuous monitoring and audio feedback to surgeon. Visual identification of the nerve does not necessarily mean functional integrity. By obtaining a vocal fold response, IONM provides confirmation that the anatomically preserved nerve is also electrophysiologically intact[2].
- Works outside the operation field.
- High specificity and negative predictive value.

Disadvantages

- Rise of operation costs due to monitoring equipments and supplies.
- Extension of the operation time.
- Additional setup time at the beginning of surgery.
- Potential false negative EMG data.
- Low sensitivity and positive predictive value

Miller and Spiegel[2] consider "Although not unique to thyroidectomy, one final concern is that surgeons simply will rely upon technology as a means of protecting the RLN rather than using anatomical knowledge and careful technique. Indeed, the fear that the availability of new technologies and devices will supplant the application of reason and clinical judgment is pervasive throughout medicine today''.

SENSITIVITY AND SPECIFICITY

Sensitivity is the ability of IONM to detect a paralyzed nerve as a percentage of the true number of paralyzed nerves confirmed by laryngoscopy.

Specificity is the ability of IONM to detect the number of electrically intact nerves as a percentage of those with normal fold motion at laryngoscopy.

Positive predictive value (PPV) is the probability that, in the absence of an EMG signal, a patient truly has a vocal fold paresis.

Negative predictive value (NPV) is the probability that, in the presence of an EMG signal, the vocal folds will be mobile.

IONM has high specificity and NPV. Chan[18], in a study on 1000 nerves, finds 94% specificity and 97% NPV. Hermann[5], in a study on 502 nerves, finds 99.3% specificity for permanent palsy and 98% for postoperative paresis with NPV of 96.6% for postoperative paresis and 98.8 for permanent palsy. Beldi[6], studying 429 nerves, confirm the same results: specificity 98% and NPV 99%.

IONM sensitivity and PPV are rather low. Sensitivity ranges between 40%[6] to 57.1%[5], with PPV of 33%[6] to 35%[18]. Hermann[5] finds a better PPV for postoperative paresis (87.1%) compared to permanent palsy (57%). Chan[18] considers that, on an overall sensitivity of 53%, IONM has 83% sensitivity for high risk nerves. The low sensitivity is caused by high rates of false negative results. False negatives results suggest RLN integrity when, in fact, the nerve has been damaged. The main cause of false negative results is stimulation distal to the site of injury. This is the reason why some authors[12,17] recommend early identification and stimulation of RLN at the level of the inferior thyroid artery, rather than near Berry's ligament. Dralle considers that vagal stimulation at the end of the procedure could raise considerably IONM sensitivity by excluding false negative results.

In conclusion, the patients who have normal nerves following IONM are likely to be normal according to laryngoscopy. On the other hand, the nerves that appear to be compromised during IONM have still a 50% probability to have normal fold motion at laryngoscopy[2].

OUR INITIAL EXPERIENCE

Our department had practiced thyroid surgery since June 2007, with an experience of 412 thyroidectomies for different types of pathologies: nodular goiter, Basedow disease, hyperfunctional adenomas and thyroid cancer. The most common procedures were: total thyroidectomy (71.2%) and hemithyroidectomy (23.6%). The operations were made by the same surgeon, with visual identification of the RLN. Since December 2013, we have started monitoring RLN nerves using a Neurosign 100 device (Figure 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.

IONM was used in only two cases: a 32-year-old woman suffering from Basedow disease and a 44-year-old male with voluminous nodular goiter. We used a 6mm orotracheal electrode for the woman and a 7 mm electrode for the man. The neuromuscular blocking drugs were used only at the beginning of the procedure. The current frequency was set for 3Hz. IONM was used for RLN localization and identification. The current intensity was set at 3 mA and was useful for localization, but failed to differentiate between RLN and other near structures, like inferior thyroid artery branches. When lowering the intensity to 0.5 mA, the nerve was easily identified. Laryngoscopy showed no vocal fold paresis or paralysis.

DISCUSSIONS

IONM is a very useful tool for identifying the nerve and for documenting its vitality at the end of thyroidectomy[11]. IONM is easy to use after the initial learning curve. The results of IONM in decreasing RLN paresis / paralysis after thyroidectomy are rather controversial. Thomush[8] considers: IONM of RLN during thyroid surgery is recommended because of significant lower rates of transient and permanent RLN palsy, in comparison with conventional RLN identification. This assessment is supported by Brennan[19] in his study (2001) on 96 monitored nerves at risk and by Robertson[20] with a retrospective study among 336 nerves. The rates of nerve paresis / paralysis were lower for monitored groups in both studies but, with no statistical significance. The authors recommend larger studies. In 2002, Thomush and Sekulla[8] presented the results of a multi-institutional prospective trial across 7133 nerves at risk. The rates for transient and permanent RLN palsy were lower for cases where IONM was used. These results were highly statistically significant.

The largest not-randomised trial was made in Germany between 1998 and 2001, including 29,998 nerves at risk[14]. The patients were divided in 3 subgroups: no RLN identification, visual RLN identification and visual RLN identification with IONM .The rates for permanent RLN paralysis were: 0.93% (no RLN identification), 0.89% (visual identification), and 0.80% (visual identification and IONM). There was no statistically significant difference between IONM and visual identification only.

These conclusions are supported by Chan[17,5] in his study on 1000 nerves at risk. The operations were

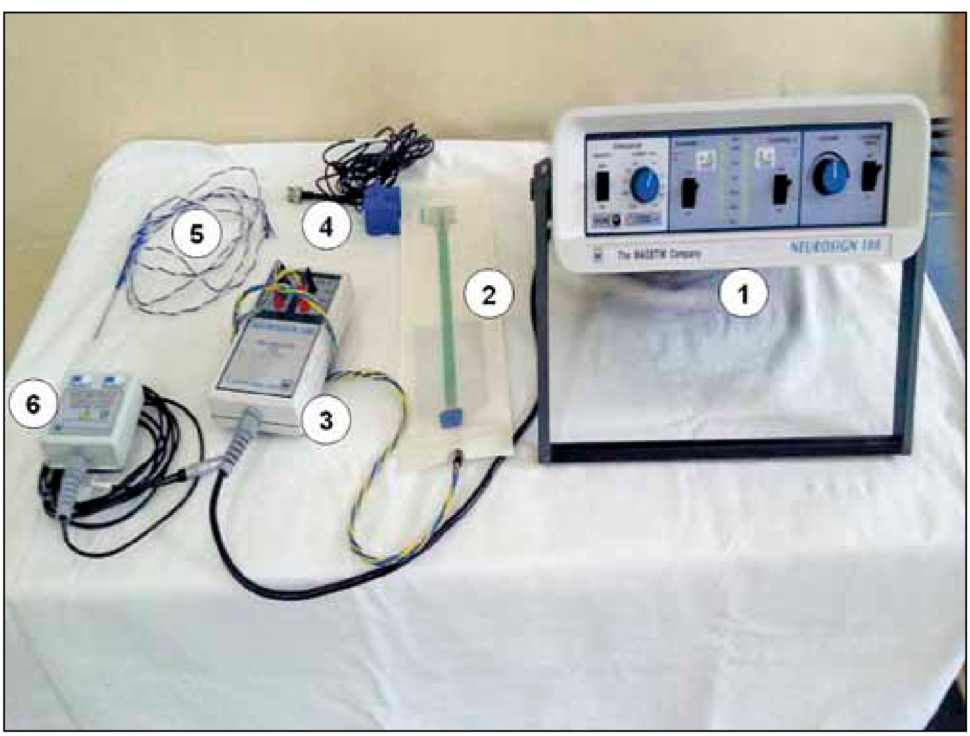

Figure 1 Neurosign 100 ENT stimulator includes: stimulator module (1), stimulator probe pod (6), preamplifier (3), mute sensor (4), bipolar concentric stimulator probes (5) and endotracheal electrodes (2).

made by the same surgeon. The patients were divided in two subgroups: visualization only (499 patients) and visualization with IONM (501 patients). There was no difference in the incidence of RLN paresis/paralysis between the groups. However, in a high risk subgroup analysis including reoperations, thyroid carcinomas and voluminous goiters, IONM was associated with a reduction of RLN paresis and paralysis.

In his study on 333 RLNs at risk, Chiang FY[13] found that early and definite identification of the RLN with IONM was a reliable way to prevent nerve injury caused by visual misidentification. Furthermore, when facing a patient with reoperative cord palsy, or when undertaking an operation in which one RLN has been invaded by thyroid cancer, the surgeon can be more confident about avoiding the risk of postoperative bilateral cord palsy with this procedure. “IONM is a reliable tool to localize the RLN and facilitate its early identification during thyroid operations, especially in difficult cases.”

Yarbrought[21], in 2004, submitted a report in which 54 patients reoperated with cervical procedure and IONM are compared with a non-monitored group of 59 patients with the same characteristics. The rates of permanent RLN injury were nearly identical (1.4 versus 1.3 favouring the unmonitored group). The Mayo Clinic study conclusion was: “Intraoperative electromyographic monitoring of the RLN in reoperative neck surgery can be performed safely, but did not decrease RLN complications in this study. Experience and routine nerve exposure remain crucial to the minimization of RLN complications”. In a comment to Yarbrought’s works, Dralle appreciates: “The main problem in recurrent laryngeal nerve monitoring is that recurrent laryngeal nerve paralysis is rare. Therefore, you need a very high number of operations to compare the results of nerve monitoring with those not using this technique”[13,21]. To demonstrate a reduction in the rate of RLN injury from 2% to 1% with intraoperative monitoring, a study group of about 1000 lobes would be required[10]. A recent retrospective review by Witt[22] was performed to compare rates of RLN injury with and without the use of an RLN monitor. Of 136 cases reviewed, monitored RLNs had a temporary injury rate of 2.8 percent and a permanent injury rate of 0.9 percent. In unmonitored RLNs, these rates were 4.8 % and 2.4%, respectively; neither rate reached statistical significance, but showed a clear trend.

RLN paresis or paralysis after thyroidectomy is not entirely due to nerve injury during surgery. There are studies that show that the cause of modification of the vocal fold functions could be intubation or other anaesthesic manoeuvres. Neuromonitoring the nerves at the end of thyroidectomy with positive response may be an argument for the surgeon in case of litigation.

A questionnaire[23] was mailed to 1685 randomly selected otolaryngologists, representing approximately half of all otolaryngologists currently practicing in the United States. A total of 685 (40.7%) of questionnaires were returned, and 81% (555) of respondents reported performing thyroidectomy. Of those, only 28.6% (159) reported using intraoperative monitoring for all cases and 44% occasionally. Respondents were 3.14 times more likely to currently use intraoperative monitoring if they used it during their training. It is interesting to note that, while only 44% of respondents used intraoperative RLN monitoring during thyroid / parathyroid surgery, greater than 60% of respondents to similar surveys reported using nerve monitoring during parotid surgery[24].

Despite the fact that young surgeons are more likely willing to use the new technology, some authors highlight that IONM brings more benefits in the hands of an experienced surgeons, mainly in difficult surgical situations.

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