Safety and Current Achievements in Thyroid Surgery with Neuromonitoring

Bezpieczeństwo i najnowsze osiągnięcia w chirurgii tarczycy z użyciem neuromonitoringu

Abstract
One of the most important complications during thyroid surgery is injury of the recurrent laryngeal nerve (RLN) which leads to dysfunction and palsy of the vocal folds. Adequate knowledge about the location of the RLN supported by neuromonitoring can help the operating surgeon to prevent this complication. Visualisation of the nerve alone seems to not be enough. Much more important is an estimation of the function of the RLN. One can say that nowadays we are in the passing era (transition period) of only visualisation of the recurrent laryngeal nerve during operation and entering the era of its neuromonitoring. Neuromonitoring gives us information about the location and function of the RLN. Using this equipment, thyroid surgery becomes safer not only for the patients but also for the operating surgeon in the way of the medicolegal consequences of surgical complications (Adv Clin Exp Med 2013, 22, 1, 125–130).

Key words: recurrent laryngeal nerve, neuromonitoring, thyroid surgery.

Streszczenie

Słowa kluczowe: nerw kraniowy wsteczny, neuromonitoring, chirurgia tarczycy.
RLN injury, which was also reported by other authors [4–6]. However, the injury of the RLN can occur even in cases with no aberrant anatomy of the laryngeal nerve. This may be caused by thermal injury, compression, traction and vacuum pressure. It is also well known that in cases of huge retrosternal goiter, thyrotoxicosis, thyroiditis after radiotherapy and in cases of central lymph node clearance, it is difficult to identify this nerve. That was a reason to introduce a new technique apart from nerve visualization, which is called intraoperative neuromonitoring (IONM).

Touching the nerve with a special electrical probe during thyroidectomy, the surgeon can evoke a stimulation of the nerve which affects vocal cord movements. Special detecting electrodes placed on the endotracheal tube can detect and convert muscle activity into acoustic and electromyographical signals [7].

IONM has been suggested as a new method, before visual identification of the recurrent laryngeal nerve, to prevent nerve palsy. And even in cases of nerve palsy, it is possible to elucidate the mechanism of the nerve injury [8].

Some studies have shown the benefits of IONM. Barczyński et al. showed that, using this method, transient paresis of the recurrent laryngeal nerve is reduced by 2.9% in high-risk patients and 0.9% in low-risk patients [9]. Other authors say that neuromonitoring significantly decreases the rate of postoperative transient and permanent RLN palsy [10, 11].

Barczynski also suggests that neuromonitoring increases the accuracy of macroscopic identification in cases of bifurcated RLNs, which prevents neuropraxia of the anterior branch of bifurcated recurrent laryngeal nerve [12].

Higgins et al. [13], based on meta-analysis evaluating 64,699 at-risk nerves, demonstrated no statistically significant difference in the rate of true vocal fold palsy after using IONM versus only identification of the nerve during thyroidectomy. He also suggests that IONM should not be considered as the standard of care and should not supplant anatomical identification of the RLN.

Chiang, based on IONM, revealed that the main reason of RLN injury during thyroidectomy is nerve traction, which results in its invisible damage [8, 14].

The nerve is prone to injury at the region of Berry’s ligament, so authors even changed the place for initial searching of the RLN, from the region of this ligament to the level of the thyroid artery.

Loss of function of the nerve may be estimated, even when the nerve is visually intact the injury is invisible, so it helps the surgeon in decision-making whether to operate or not on the other side, to prevent casual bilateral nerve palsy.

Goretzki suggests that in cases, after one lobe dissection, when the nerve is visible but not functioning on one side, further surgery on the other lobe may be postponed in order not to risk bilateral vocal cord paralysis [15].

Documentation from neuromonitoring can help to estimate whether the surgeon or another reason caused the palsy of the recurrent nerve, which can be helpful in medicolegal litigation of surgeons.

The International Neural Monitoring Study Group, formed in 2006, has gained widespread acceptance of neuromonitoring as an adjunct to the gold standard of visual nerve identification [2].

Neuromonitoring can locate the point where the loss of signal occurred with an identification of how and when the nerve was injured. These create an eventual possibility of repairing the nerve or removing the obstacle.

After accidental injury, a damaged nerve can be found using IONM, and a proper anastomosis could be performed by the surgeon.

Only IONM can identify the division of the RLN into the anterior motor branch and the posterior sensor branch. The sensor branch could be, depending on the circumstances, treated as a whole nerve, which can cause damage to the anterior motor branch [2].

Standards of Neuromonitoring

There are certain minimal elements for optimal IONM, which include the necessity of preoperative laryngoscopy (L1) to evaluate the functional status of the vocal cords. The next step is initial dissection and stimulation of vagal and laryngeal nerves (V1, R1). These elements allow for verification of the IONM system and subsequent neural mapping of the recurrent nerve before surgery. After dissection of the thyroid gland, the surgeon can test postoperative glottis function, stimulating once again the laryngeal and vagal nerves (R2, V2). Postoperative laryngoscopy (L2) is necessary to evaluate the correlation between postoperative stimulation and essential glottic function. All these elements are shortly known as L1- V1- R1- R2- V2- L2.

Preparation for Surgery

Adequate cooperation with an anesthesiologist is a very important part of neuromonitoring success. Placement of the endotracheal tube should take into
consideration changes of the position of the tube during repositioning of the neck for surgery. The depth of insertion of the endotracheal tube has been researched in the Asian population. Women have a slightly smaller depth of insertion, 19.6 ± 1 cm, compared to men, 20.6 ± 0.97 cm [16].

The position of the tube could change during the repositioning of the patient. The tube can be displaced up to 21 mm inward and 33 mm outward, when the patient is repositioning from the neutral to full neck extension position [17].

The anesthesiologist’s protocol should include initial, short time relaxation agents for intubation, and then anesthesia should be carried out with no muscle relaxation, to achieve good response from the vocal cords.

A xylocaine lubrication agent shouldn’t be used for lubrication of the endotracheal tube as a way to decrease the potential local paralytic agent.

All substances known as neuromuscular blocking agents should be avoided, because they can reduce the amplitude of evoked responses.

**Equipment**

Modern monitoring systems can be divided into audio-only systems and systems which show visual and audio waveform information, including evoked waveforms. The second system gives us more information about the morphology, amplitude, latency and threshold, which is very important particularly in estimating and finding the place of injury of the RLN. The general scheme of neuromonitoring equipment is shown in Fig. 1.

Continuous vagal nerve stimulation is a system which uses special probes that stimulate the vagus during the time of thyroidectomy. This system can warn the surgeon before imminent nerve function impairment [18]. Continuous vagal nerve stimulation during thyroid surgery has a distinct impact on the autonomous nervous system balance, which can be reliably assessed through analysis of heart rate variability [19].

Recording electrodes are generally needle-based or endotracheal tube-based. Needle-based supports more information, but can provide more injury, like vocal cord laceration, hematoma, infection and deflation of the endotracheal balloon. They also record signals only on one side, which requires its repositioning during surgery. Endotracheal tube-based electrodes provide EMG data from the vocal cord.

Stainless steel electrodes should be placed on the endotracheal tube on a surface that is exposed at the glottis level. It is important that adhesive pad electrodes should stick firmly to the vocal cords, so for each patient, the largest size of endotracheal tube should be used. This not only gives better contact with the vocal cords but also improves impedance.

Chiang uses 6 mm endotracheal tubes for women and 7 mm for men [8].

Most equipment-related problems are due to malposition of the endotracheal tube recording electrodes.

The position of the endotracheal tube should be checked a second time, when the patient is fully in position. This can be done by direct laryngoscopy or using a fiberscope applied to the endotracheal tube. Another tube-position verification method is a “tap test”. Tapping the midline larynx with a finger at a level of the thyroid cartilage can evoke a nerve-like response, a waveform seen on the monitor. The mechanism of this action is poorly understood [2].

During operation, the surgeon visually identifies the vagus and recurrent laryngeal nerve and its neuromonitoring response. Adequate responses from both of these nerves give information about good positioning of the endotracheal tube. In case of malposition of the tube, its repositioning during surgery is much more difficult. Lu at al. showed that optimal tube placement was possible at first intubation in 94% of patients [16].

Stimulating electrodes could be bipolar or monopolar and can be configured as a surgical tool. Bipolar is more sensitive, but monopolar is better.
for searching (mapping) the laryngeal nerve, because can reach a wider area.

Electrocautery units should be placed at some distance from the monitoring device because they may produce electrical interference. Some newer neuromonitoring devices are able to monitor while using monopolar electrocautery. Special muting cables, attached to the electrocautery can temporarily control signals in other, older equipment. The device is compatible with Harmonic and Ligasure technologies.

The monitor as a source of visual information should be placed in visual access of sight of the surgeon.

After positioning the tube in the patient, the monitor parameters should be checked out. The impedance should be less than 5 kΩ, with an imbalance between the electrodes of less than 1 kΩ. Lower electrode impedance, less than 5 kΩ per electrode, suggests good contact between the electrodes and vocal cords. High electrode imbalance means that this contact is not sufficient and requires repositioning or exchanging of the tube [8].

Another parameter of the monitor is the threshold, which should be set at a level of 100 μV, or up to 200 μV in the case of interfering signals of spontaneous respiratory waveforms.

The stimulating probe ought to be set at a value 1 to 2 mA. 2 mA is better for mapping and searching for the laryngeal nerve. After finding and dissecting the nerve, it does not evoke greater amplitude. 1 mA should be used for stimulation.

The probe’s output is pulsatile, 4 signals per second. It is important to keep the tip of the probe in one place for some time, rather than intermittently touching very quickly.

If stimulation of the RLN and vagus shows no EMG activity, excluding equipment problems, this means that loss of signal (LOS) strongly suggests neural injury.

A surgeon after LOS should consider the mechanism of injury of the nerve and the decision whether or not to operate the second lobe ought to be considered.

When the RLN is being stimulated and there is no EMG activity, the first step is assessment of laryngeal twitch by the surgeon with vagal stimulation on that side. The laryngeal twitch is the response to stimulation of the nerves and the surgeon can “feel” this response, by putting his index finger behind the larynx and feeling the delicate contractions of the muscles. The intraoperative estimation of loss of signal scheme is shown in Fig. 2.

A real cut of the nerve is classified as a type 1 RLN injury. Type 2 injuries are after clip placement, overheating or suturing the nerve, when the nerve exists as an anatomical structure, but has no conductivity.

### Definitions

The neuromonitoring system has special definitions, which have to be described.

The amplitude of the wave, which was evoked by stimulation of the vagal or RLN, is typically a biphasic waveform which represents the summed motor action. The height of this wave is the distance between its vertical top and lowest point (peak to peak). Its amplitude is correlated with the number of muscle fibers participating in this action. During normal speech, this amplitude ranges from 100 to 800 μV.

During operation, the amplitude may be affected by fluid or blood in the place of stimulation, inadequate probe-nerve contact, covering of the nerve by the fascia, the environmental temperature and endotracheal tube electrode surface position.

The threshold is defined as minimal stimulating electricity which triggers minimal EMG activity. The vagus and RLN start to be activated at approximately 0.3 to 0.4 mA, when the nerve is dry and well-dissected. Maximum stimulation of all nerve fibers is achieved at 0.8 mA. Beyond this point, increasing stimulation does not give a better response in the EMG, so rational stimulation for most cases is established at 1 mA. The use of 2 mA is suitable in mapping the RLN, because it gives a greater sphere of tissue around the probe tip.

Wu from Taiwan [20] says that current higher than 1 mA is well tolerated by the nerves, but based on his study on piglets, he showed that 1mA should be selected to minimize the potential risk of nerve damage and false results during IONM.

Latency is described as the time of speed of stimulation-induced depolarization. It depends on the distance to the vocal cord, so depends on the level of stimulation. This time is different during stimulation of the vagal nerves. The latency on the left vagal nerve is longer, because the left RLN has a longer way to the vocal cord, wrapping around the aorta.

The latency for the RLN from the level of thyroid cartilage is 3.5 milliseconds (ms), the left vagal nerve stimulated at the same level is 8.1 ms, and the right one is 5.4 [2].

The audio and visual neuromonitoring systems have the largest number of advantages. The operating surgeon can achieve quantitative data from vagal and laryngeal nerves and the possibility to compare nerve signals before and after dissection of the thyroid gland. It also gives the surgeon the opportunity to find the mechanism of eventual nerve injury and can confirm the functionality of the RLN after its dissection, which is very frustrating and dangerous for a surgeon. Another advantage of this procedure is that it can help to elucidate the surgical pitfalls.
and help to improve surgical technique and orientation in the operating field [8]. Generally IONM extends the time of the thyroid operation but provides much more safety not only for the patient but also for the operating surgeon in the way of the medicolegal consequences of surgical complications.

References


Address for correspondence:

Paweł Domosławski
1st Department and Clinic of General,
Gastroenterological and Endocrinological Surgery
Wrocław Medical University
Skłodowskiej Curie 66
50-369 Wrocław
Poland
Tel.: +48 601 572 162
E-mail: pawel.domoslawski@umed.wroc.pl

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