INTRAOPERATIVE ELECTROPHYSIOLOGICAL MONITORING OF THE RECURRENT LARYNGEAL NERVE IN THYROID SURGERY – IS IT WORTHWHILE?

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ABSTRACT

Recurrent laryngeal nerve (RLN) injury is the most problematic complication impacting on the decision whether or not to perform total or completion thyroidectomy. Recurrent nerve paralysis is a less frequent complication when the nerve is routinely identified. A simple technique will be described for identifying the recurrent laryngeal nerve with a nerve stimulator to prevent damage to the nerve during thyroid surgery. 34 women and 16 men undergoing thyroid surgery over 12 months were subjected to intraoperative nerve stimu-lation with increasing voltage increments by both the traditional bipolar and concentric bipolar electrodes until both light and sound (audiosignal) indicators on the nerve monitor were positive. All recurrent laryngeal nerves with associated preoperative normal vocal cord mobility were identified successfully and the location of the nerve was clearly established by the lowest stimulating current, which evoked the audiosignal response only when the probe was over the nerve, which was immediately confirmed by direct visualization. The integrity of these RLNs distal to the point of stimulation was confirmed on completion of the surgery. The threshold for stimulation of the recurrent nerve varied from 0.2 to 1 milliAmpere (mA) (mean 0.37 mA) for the standard bipolar and 0.1 to 1mA (mean 0.27 mA) for the concentric bipolar electrode. The traditional bipolar electrode threshold stimulation was consistently higher than the concentric bipolar and had less variability. Comparison between minimal stimulation levels

with the concentric bipolar probe pre-dissection of the recurrent laryngeal nerve (that is at the time of initial nerve identification) mean 0.37 mA (range 0.2- 1 mA) and post-thyroidectomy (that is after removal of the surgical specimen) mean 0.369 mA (range 0.1- 2 mA) showed no significant change. There were no endotracheal difficulties in our study since the electrode adheres to the normally used endo-tracheal tube. Mechanical or electromechanical stimulation of tissue adjacent to the RLN has been helpful in indicating its close proximity when dissecting. These aids may reduce the risk of iatrogenic RLN injury, particularly during redo surgery. In our study stimulation artifacts were also quite common with instrumentation contact, but did not interfere with monitoring to any great extent. False-positive responses may also occur primarily due to misinterpretation artifact. Electrophysiologic monitoring of the RLN is shown to reduce the incidence of RLN injury, its benefit most likely is related to augmentation of the surgeon's ability to identify and thus protect the RLN from injury. Surgeon's skill, experience, and judgement will remain the most important elements in preventing RLN injury.

INTRODUCTION

Injury of the recurrent laryngeal nerve (RLN) is one of the most frequent complications in thyroid surgery. It leads to a significant morbidity of up to 20%, depending on the type of surgery being performed[1]. Recurrent nerve paralysis is a less frequent complication when the nerve is routinely identified and correctly prepared [2]. There was insufficient evidence to support that the identification of RLNs during surgery would be a significant factor in reducing the likelihood of RLN paralysis. However, RLNs should be identified to avoid iatrogenic injury and subsequent paralysis. Meticulous surgical technique should be applied in patients whose results of fine-needle aspiration biopsy suggested malignancy, as there is the possibility of difficult surgery and potential iatrogenic RLN paralysis in this group of thyroid patients [3]. RLN injury is the most problematic complication impacting on the decision whether or not to perform total or completion thyroidectomy [4]. Echeverri and Flexon [5] have made a retrospective review to describe a simple technique for identifying the RLN with a nerve stimulator to prevent damage to the nerve during thyroid surgery. Routine systematic exposure of recurrent laryngeal nerves reduces the incidence of complications in thyroid surgery to a minimum. The risk of recurrent nerve palsy increases with extent and difficulty of the operation, with the highest risk for nerve lesions seen in re-operations and near-total resections [(6)].

Aim of work

Prevention of recurrent laryngeal nerve injury during thyroid surgery by using the technique of nerve stimulation.

PATIENTS AND METHODS

Fifty patients undergoing thyroid surgery over 12 months (June 2003 to May 2004) were assessed for inclusion in the study. These included 34 women and 16 men with an age range of 22-62 years median age 40. Ten patients had undergone previous thyroidectomy .One patient had a preoperative vocal fold abnormality namely right cord paralysis. The indications for surgery were suspected/ confirmed malignancy, huge goiter or failure of medical treatment. The operations varied from partial thyroidectomy, subtotal thyroidectomy, near total thyroidectomy, total thyroidectomy and total thyroidectomy with neck dissection. This study describes the use of the Neurosign 100 Nerve Monitor (Magstim, Whitland, Carmarthenshire, Wales) in the identification and assessment of RLN integrity during thyroid surgery. All patients in this study were dealt with in the Endocrine Surgery Unit in Mansoura University Hospital. The objective of this study was to investigate the benefit of a new commercially available non-invasive technique of laryngeal nerve monitoring in thyroid surgery. In particular to assess its ability to identify and confirm nerve localization, case of use, establish parameters for its use and to investigate possible prognostic significance.

The Neurosign 100 Nerve Monitor is a device that was approved for use by Ministry of Health in 1997. The device consists of:

1) Laryngeal electrode which stick on the endotracheal tube at the glottis level and skewed anterolaterally for local cord contact (Fig 1).
2) Cable assembly.
3) Preamplifier pod
4) Main unit (Fig 2).
5) Stimulatory pod.
6) Stimulatory probes (Figs 3, 4).

The endotratheal tube interfaces with the Neurosign 100 a monitor that continuously tracks electromyography (EMG) activity and has a built-in pulse generator for electrically evoked EMG. The cost of the Neurosign 100 Nerve Monitor was 37000 Egyptian pound and the disposable electrodes were 300 Egyptian pound per case. Data were collected for all patients undergoing thyroid surgery over 12 months period on a prospective basis. Fifty patients undergoing thyroidectomy were evaluated and constituted the study group. Informed consent was obtained for each patient.

All our patients were subjected to :

1) History taking.
2) Clinical examination.
3) Laboratory investigations:
   - Routine investigations (complete blood picture, liver function tests, fasting & 2 hours postprandial blood sugar & serum creatinine).
   - Thyroid function tests (serum T3, T4, TSH)
4) Radiological investigations,
   - Thyroid ultrasonography.
   - Thyroid radioactive scanning.
5) Preoperative laryngeoscope.
6) Thyroidectomy.
7) Intraoperative nerve stimulation and monitoring.
8) Postoperative laryngeoscope.

Prior to surgery the laryngeal function was assessed with laryngeoscopy. The endotracheal tube was selected according to the patient's size. At intubation the electrode (stick on electrode) was sited on the endotracheal tube at the anticipated level of the true vocal cords by the anaesthetist. The electrode is not surgically invasive and is manufactured using a flexible polyester substrate with conductive ink tracks to measure EMG activity sitting in the posterior glottis after intubation. The electrode wa connected to the preamplifier pod and the Neurosign 100 signal processing unit in the normal manner. The preamplifier pod were placed on the side of the table. The stimulator was set at 30 mHz with variable increasing voltage and attached to either a traditional bipolar or concentric bipolar probe. To allow nerve monitoring surgical Procedures were carried out under general anaesthesia, without the use of muscle relaxants except during intubation a short acting muscle relaxant was used. After premedication with midazolam (1-2 mg IV), the patients were taken to the operating room, where they were monitored with ECG pulse oximetry, and non invasive BP measurement. General anaesthesia was induced with sodium thiopental (4-5 mg/kg) and fentanyl

(1μg/kg). Succinylcholine (1mg/kg) was used to facilitate intubation of the trachea with the modified endotracheal tube. Anaesthesia was maintained with nitrous oxide/oxygen and isoflurane. The lungs were ventilated mechanically, keeping the endexpired carbon dioxide in the range of 28 to 32 mm Hg. Also baseline respiratory activity was observed in all patients.

Thyroidectomy was carried out as follow:

Step 1 : The patient was laid in semi-Fowler position with the neck hyperextended and a small pillow at the area of the upper thoracic spine, beneath the shoulders. Support under the head may be used.

Step 2 : The site of the incision was one fingerbreadth above the sternal notch. Incision is symmetrical and is carried out through the superficial fascia (subcutaneous fat and platysma). Good hemostasis by electrocoagulation or ligation using silk was established.

Step 4 : Formation of flaps was done by blunt dissection, elevate the upper flap to the notch of the thyroid cartilage and the lower flap to the jugular (sternal) notch.

Step 5 : Opening of the deep fascia is accomplished by a longitudinal midline incision along the raphe of the strap muscles.

Step 6 : Exposure and mobilization of the gland was done by the index finger of the surgeon is gently inserted between the thyroid and the muscles.

Step 8 : Retraction of the lobe medially and anteriorly was done then ligation of the middle thyroid vein.

Step 9 :

a) Identification of the recurrent laryngeal nerve by blunt dissection into the tracheoesophageal groove. Electro physiological stimulation was carried out (described below).
b) Identification and protection of the parathyroids.
c) Ligation of the inferior thyroid artery.
d) Ligation of the lower pole vessels.
e) Careful ligation of the upper pole was done during which ligation of the superior thyroid artery within the gland has taken place.
f) Dissection of the lobe from the trachea by dividing the gland between straight mosquitoes.
g) If the pyramidal lobe was present,

its removal together with the lobe was done.

h) Meticulous hemostasis.

Step 10 : Closure in layers was carried out with suction drainage.

Standard surgical techniques were followed in each case. No additional dissection beyond the standard operative technique was performed to improve nerve exposure. After mobilization of the thyroid lobe the recurrent laryngeal nerve identification was carried out both clinically and by placing the stimulatory probe against the nerve or adjacent tissue at the expected site confirming correct identification of the primary circuit. After identificat ion, to establish the correct stimulating current (ranging from 0.1 mA to 3 mA) the nerve was stimulated with increasing voltage increments until both light and sound (audiosignal) indicators on the nerve monitor were positive. These signals are an evoked EMG which was obtained (stimulus response threshold). Both the traditional bipolar and concentric bipolar electrodes were used and the minimal threshold for stimulation was noted for each probe. laryngeoscopy was done at the approximate midpoint, and at the end of the surgical procedure to make sure that the electrode is in place. Following thyroidectomy the lowest threshold of stimulation for the recurrent laryngeal nerve were recorded and compared to pre-thyroidectomy levels. Significant EMG events elicited during surgery and artifact responses were observed. - Patients after surgery were assessed with laryngeoscopy within 2 weeks of operation.

Table 1: Post Operative Pathological Diagnosis in the Present Study

Pathological diagnosis	***No. of patients***
Simple Multi Nodular Goiter	**21**
Toxic Nodular Goiter	**10**
Papillary Thyroid Carcinoma	**5**
Follicular Thyroid Carcinoma	**2**
Follicular Thyroid Adenoma	**1**
Hashimoto Thyroiditis	**1**
Recurrent Simple Nodular Goiter	**4**
Recurrent Toxic Goiter	**3**
Recurrent Papillary Thyroid Carcinoma	**2**
Recurrent Hurthel Cell Tumour	**1**
Total	**50**

P = 0.001

Table 2:Recurrent laryngeal nerve stimulus response threshold for standard bipolar stimulatory probe

Stimulus Threshold mA	**Number of Nerves**
0.2	**41**
0.3	**11**
0.5	**43**
0.7	**3**
1.0	**2**
Mean 0.37	Total **100** nerves
P = 0.001	

*Table 3:***Recurrent laryngeal nerve stimulus response threshold for concentric bipolar stimulatory probe.**

Stimulus threshold mA	***Number of nerves***
0.1	**23**
0.2	**26**
0.3	**30**
0.5	**19**
0.7	**1**
1	**1**
Mean 0.27	Total 100 nerves
P = 0.0014	

Table 4:**Comparison between minimal stimulation levels with the concentric bipolar probe pre-dissection of the recurrent laryngeal nerve (that is at the times of initial nerve identification) and post-thyroidectomy (that is after removal of the surgical specimen).**

Predissection (mA)	***Postdissection (mA)***	***No. of nerves***
0.2	**0.1**	**13**
0.2	**0.2**	**20**
0.2	**0.5**	**8**
0.3	**0.1**	**2**
0.3	**0.2**	**4**
0.3	**0.5**	**5**
0.5	**0.2**	**12**
0.5	**0.5**	**28**
0.5	**1.0**	**1**
0.5	**1.5**	**1**
0.5	**2**	**1**
0.7	**0.5**	**2**
0.7	**0.7**	**1**
1.0	**1.0**	**1**
1.0	**0.5**	**1**
Mean **0.37**	Mean **0.369**	Total **100** nerves
P = 0.0013	*P = 0.0019*	

Table 5:Comparison of our study and previously reported recurrent laryngeal nerve electrophysiological monitoring techniques

Series	***Electrode type***	***Electrode location***	***Stimulus current (mA)***
Rice Dhand Cone-Wesson (7)	Intramuscular	Thyroarytenoid Muscle	0.2-0.5
Beck DL and Maves MD (8)	Intramuscular	Thyroarytenoid Muscle	0.25-0.65
Maloney RW et .al (9)	Intramuscular	Posterior cricoarytenoid Muscle	0.25-1.0
Rea (10)	Surface array	Postcricoid	0.5
Eisele (11)	Surface endotracheal tube integrated	Glottic	0.2-0.6
This study	Stick-on fitted endotracheal tube	Glottic	0.2-1.0

P = 0.002

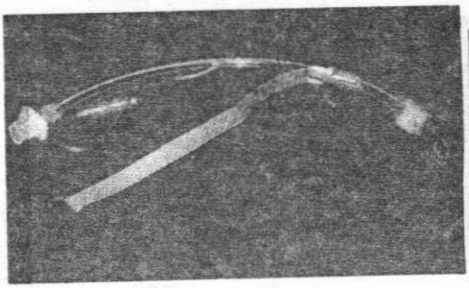


Fig (1) : The laryngeal electrode that stick on the endotracheal tube at the glottis level and skewed anterolaterally for local cord contact.

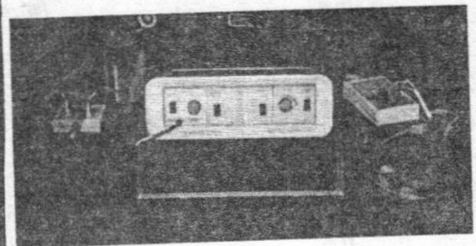


Fig (2) : The main unit.

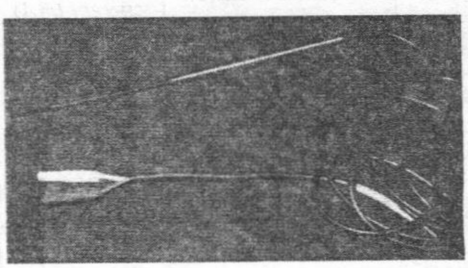


Fig (3) : The traditional bipolar stimulatory probe.

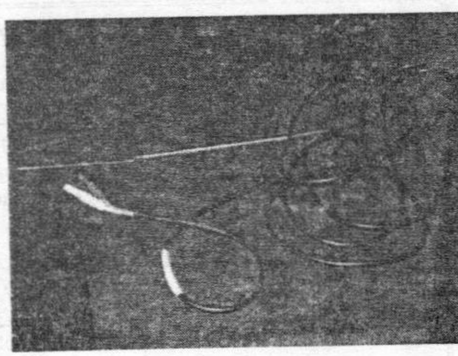


Fig (4) : The concentric bipolar stimulatory probe .

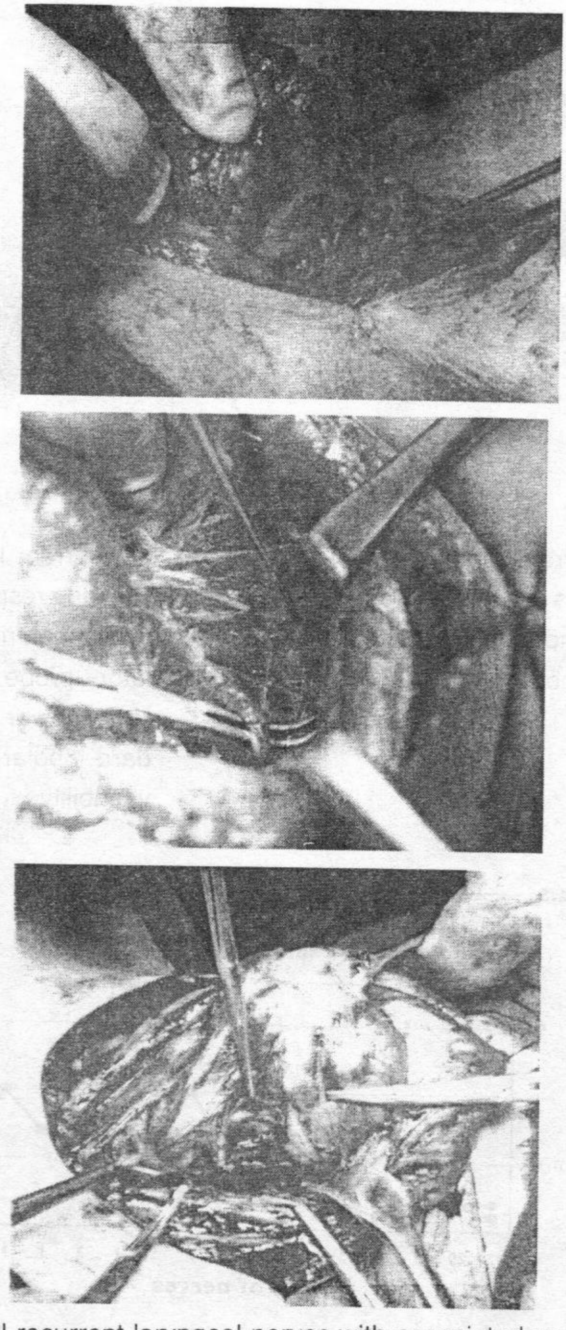
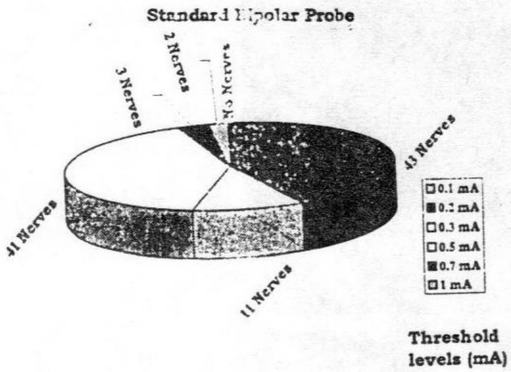


Fig (5.6.7) : All recurrent laryngeal nerves with associated preoperative normal vocal cord mobility were visually identified successfully.



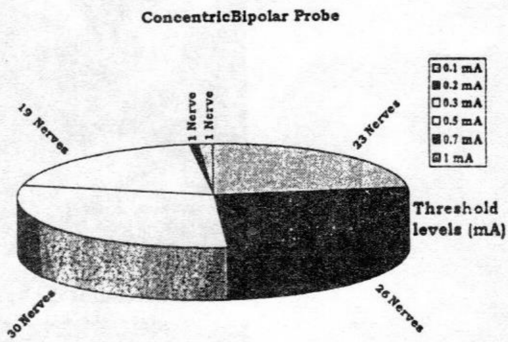


Fig (8) : Recurrent laryngeal nerve stimulus response threshold for standard bipolar stimulatory probe.

Fig (9) : Recurrent laryngeal nerve stimulus response threshold for concentric bipolar stimulatory probe. It was consistently lower than the standard bipolar and had more variability.

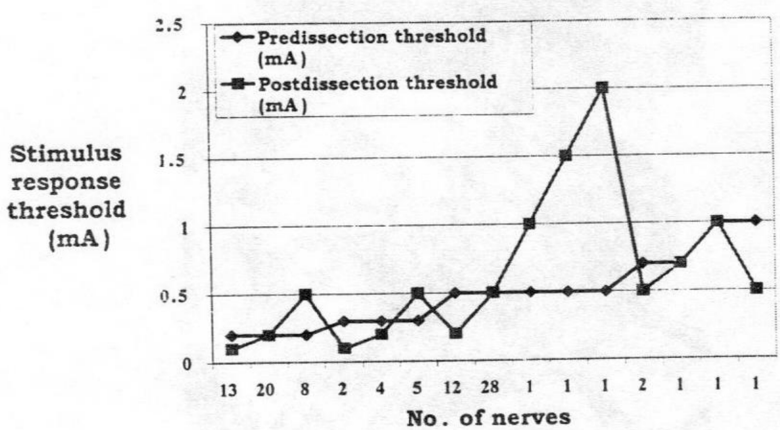


Fig (10) : Comparison between pre-- and postdissection threshold levels .

DISCUSSION

Today thyroid surgery is a routine operation which carries few complications, if performed by a properly trained surgeon. One structure that does remain at risk, however, is the RLN, particularly in situations where there has been previous surgery. Although rarely permanent, the incidence of damage to the RLN during routine thyroid surgery is of the order of 0.5-3 percent (12). Despite significant advances in surgical technique there is still a potential danger to the laryngeal nerves any time the thyroid bed is explored. Mechanisms of intraoperative nerve damage include division, laceration, stretch or traction, pressure, crush, electrical, ligature entrapment, ischemia, and suction injury (13). Most surgeons advise identifying rather than avoiding the recurrent laryngeal nerve when performing thyroid surgery and this is associated with a significantly lower rate of temporary and permanent paralysis. On the other hand the superior laryngeal nerve is not routinely identified in uncomplicated thyroid surgery (14). Another benefit of RLN monitoring is immediate audible and visual feedback of mechanically evoked potentials so that the surgical technique can be modified when something potentially harmful is being done to the nerve. In addition, nerve monitoring allows assessment of nerve integrity at the end of dissection. With electrophysiologic monitoring, the stimulus response threshold may be higher than the predissection threshold. If a nerve conduction block is noted, the surgeon should examine the RLN carefully to search for an identifiable and potentially correctable nerve injury. If the nerve is included in a ligature, the suture should be released because functional recovery may result. If RLN transection is identified intraoperatively, nerve repair should be performed (5).

The ideal monitoring system should be harmless, non invasive, reliable and act as an early warning to alert the surgeon of trouble before it occurs while discounting unrelated activity such as from electrocautery equipments (8). Stimulus response thresholds in the present study with glottic surface electrodes ranged from 0.2 to 1mA. mean 0.37mA for the traditional bipolar and 0.1 to 1mA. mean 0.27mA for the concentric bipolar electrode (Tables 2 & 3). These values compare favorably with prior reports of RLN electrophysiologic monitoring by intramuscular laryngeal electrodes (Table 5). The variability in threshold response observed in this study may be related to differences in the degree of RLN exposure. A nerve insu-lated by adjacent soft tissue may need a higher stimulation current than a more exposed nerve.

One patient with intraoperative changes in stimulus thresholds up to 0.3 mA had normal postoperative vocal cord motion. One patient had an intraoperative stimulus threshold elevation of 0.1 mA, yet developed temporary vocal cord motion impairment of 2 days duration. Thus, although minimal elevation of the stimulus threshold for the RLN generally predicts normal postoperative vocal cord function, our results indicate that a temporary vocal cord paresis can still occur in this setting. This result is similar to those reported by Eisele [11]. On the other hand,one patient had an intraoperative stimulus threshold elevation of 1 mA for left recurrent laryngeal nerve, left vocal cord paresis partially reversed 6 months after surgery. Thus, such an elevation in the stimulus threshold does not necessarily foretell permanent vocal cord paralysis. In one patient with multinodular goiter and right vocal cordmotion impairment, postoperative recovery of vocal cord motion was predicted by intraoperatively electrically evoked threshold responses with stimulating current of 1mA for the traditional probe and 0.7mA for the concentric probe. Almost similar results were reported by Eisele [11].

It has been suggested that the system is helpful not only in confirming correct identification of the nerve in its usual course, but for the 0.2- 0.4 per cent of individuals who have a non-recurrent laryngeal nerve [12]. A useful adjunct to the system is the appearance of lesser EMG potentials when working close to the RLN. This probably results from small currents generated by the electropotential of metal instruments. This phenomenon is best appreciated when neuromuscular relaxants are not being used and can be very helpful in locating the nerve itself [13].

In this study the advantages of the stick-on electrode (on the endotracheal tube) was simillar to that reported by Eisele [11]. They include simplicity in establishing electrode contact and, should tube malposition occur during surgery, in reestablishing electrode contact. Because the use of surface EMG electrodes is noninvasive, the risk of laryngeal injury is less than the risk with the use of intramuscular laryngeal electrodes. The incorporation of the electrodes into an endotracheal tube simplifies management of the electrode hardware and keeps the electrodes out of the surgeon's way. Owing to tubesize limitations, the use of this system for RLN monitoring is contraindicated by anatomic restrictions, including pediatric patients and significant tracheal narrowing. In addition, any factors that impede adequate electrode contact at the level of the glottis (i.e., laryngeal anatomic distortion or scarring) make use of this system unfeasible. Another advantage is the use of normal endotracheal tube which will not kink after intubation, so it will not result in intraoperative tube obstruction like that occurred with flexible silicone tube [9].

A disadvantage of this system is the cost of the laryngeal electrode which is 300 Egyptian Pound. Also the Neurosign 100 Nerve Monitor costs 37000 Egyptian Pound. Timon and Rafferty [14] reported that their study was to address issues quantifying the parameters required for successful stimulation using the Neurosign 100. The Neurosign 100 is commercially available and there were no endotracheal difficulties in our study since the electrode simple adheres to the normally used endotracheal tube. Further advantages include the fact that Neurosign 100 is portable, reliable and also allows auditory and visual signals of the EMG response in real time. This makes it ideal for the operating room with a two-channel unit that allows continuous monitoring. Eisele [11] mentioned that the use of electrophysiologic monitoring of the RLN is analogous to facial nerve monitoring during neurologic surgical procedures in that the intrinsic laryngeal muscles, like the facial muscles, represent a broad muscle receptor field for recording EMG activity. Any of the intrinsic laryngeal muscles can thus serve for EMG recording during RLN monitoring. The system evaluated in his study most likely records activity primarily from the thyroarytenoid muscles, but EMG contributions from the other intrinsic laryngeal muscles, in particular the lateral cricoarytenoid muscles, may occur. There is no doubt that the key to a low complication rate with respect to the RLN in thyroid surgery is meticulous surgical technique, with early identification of the nerve. The use of the nerve monitor has enabled confirmation of recurrent laryngeal nerve identification. Mechanical or electromechanical stimulation of tissue adjacent to the RLN has been helpful in indicating its close proximity when dissecting. These aids may reduce the risk of iatrogenic RLN injury, particularly during redo surgery. In addition, stimulation of the RLN itself appears to offer a sensitive means of assessing RLN integrity during thyroid surgery. Clarification of RLN integrity on one side allows the surgeon to proceed with confidence to the contralateral side during bilateral dissection (15).

Reasonable indications for RLN monitoring are conditions that may render RLN identification difficult; these include reoperation, prior radiation therapy, malignancy, and the presence of anatomic distortion, for example by goiter or large tumor. In addition, monitoring may be beneficial in the setting of preoperative vocal cord dysfunction so that neural integrity can be assessed intraoperatively and the potential for functional recovery predicted. Several arguments support the use of intraoperative nerve monitoring for routine thyroidectomy cases. For one, the surgeon can not always predict whether a case is routine. If the monitoring equipment is always set up, monitoring can be performed if needed. Also, nerve monitoring can speed the surgical dissection by confirming the anticipated location and course of the nerve (11).

Use of the Neurosign 100 Nerve Monitor did not increase surgical set up time appreciably and allowed both identification and confirmation of the recurrent laryngeal nerves with a potential prognostic ability however, there are a number of potential drawbacks. Disadvantages include the necessity of having the device available, however, these and similar nerve monitors are now available in otolaryngology units for the monitoring of the facial nerve in mastoid and parotid surgery (14).

In our study stimulation artifacts were also quite common with instrumentation contact, but did not interfere with monitoring to any great extent. Use of the Neurosign 100 requires the cooperation of anaesthetic colleagues for proper placement and the use of no or short acting muscle relaxants.

Conclusion

From this study we concluded that the use of the bipolar probes which set at 30 Hz and 0.5 mA is recommended for intraoperative recurrent laryngeal nerve monitoring during thyroid surgery. But this will not substitute the surgeon's skill, experience, and judgement. If electrophysiologic monitoring of the RLN is shown in the future to reduce the incidence of RLN injury, its benefit will most likely be related to augmentation of the surgeon's ability to identify and thus protect the RLN from injury. The benefit is also likely to be a result of the surgeon having been alerted by neurotonic discharges to potentially injurious manipulation and having modified the surgical technique to minimize nerve trauma.

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التعرف على العصب الحنجرى الراجع أثناء جراحة الغدة الدرقية بالطريقة الكهروفسيولوچية - هل هى طريقة مجدية ؟

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من قسم الجراحة العامة - وحدة جراحة الغدد الصماء - كلية طب المنصورة

تعتبر إصابات العصب الحنجرى الراجع أثناء جراحات الغدة الدرقية المختلفة من أكثر المشكلات صعوبة وخطورة فى مثل هذه الحالات. يهدف هذا البحث إلى تقييم طريقة التعرف على العصب المذكور باستخدام طريقة كهروفسيولوچية ويستخدم فى ذلك جهاز خاص يسمى (نيوروساين ١٠٠ - Neurosign 100) يقوم بتنبيه العصب كهربيا أثناء الجراحة. أجرى هذا البحث على ٥٠ مريضا خضعوا لعمليات مختلفة شملت إستئصال جزئى وكلى لتضخمات حميدة وأورام خبيثة للغدة الدرقية. أكدت نتيجة هذا البحث أن استخدام الجهاز المذكور يسهم بنسبية كبيرة جدا فى التعرف على العصب أثناء الجراحة وينبه الجراح إلى مكان العصب وبالتالى يتفادى تعرض هذا العصب للخطر أو الجرح أو القطع بواسطة الجراح. ولكن يعيب هذا الجهاز أن التكلفة الاقتصادية للحالة الواحدة مرتفعة. ونخلص من هذا البحث أن استخدام الطريقة المذكورة للتعرف على العصب هو أسلوب جراحى فعال لتفادى الاصابات ولكنه لايمكن أن يحل محل مهارة وخبرة الجراح وحكمه على الأمور الجراحية .