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Continuous intraoperative nerve monitoring in thyroidectomy using automatic periodic stimulation in 256 at-risk nerves

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ABSTRACT

INTRODUCTION Automatic periodic stimulation of the vagal nerve during thyroidectomy provides real-time feedback of recurrent laryngeal nerve function intraoperatively. To assess the validity of this device, the ability of monitoring to predict recurrent laryngeal nerve palsy was determined and the incidence of recurrent laryngeal nerve palsy recorded.

MATERIALS AND METHODS All thyroidectomies using APS® (Automatic Periodic Stimulation, Medtronic) nerve monitoring were reviewed over a 27-month period. Changes in signal amplitude and latency during thyroidectomy were recorded from saved data. Postoperative fibreoptic laryngoscopy determined the incidence of vocal cord immobility and recovery of nerve function was assessed from follow-up letters.

RESULTS A total of 256 at-risk nerves were examined (132 hemi- and 62 total thyroidectomies) in cases involving benign and malignant disease. Permanent recurrent laryngeal nerve palsy occurred in six (2.3%) lobectomies and transient recurrent laryngeal nerve palsy occurred in two lobectomies (< 1%). Sensitivity for detecting postoperative vocal cord immobility was 100% and specificity 85% if the end amplitude was 50% below baseline. The positive predictive value when amplitude was 50% below baseline was 18%. The negative predictive value when amplitude was 50% above or equal to baseline was 100%. Intraoperatively, the amplitude was 50% below baseline more frequently in the vocal cord immobility group (t-test, $P < 0.015$). No vagal nerve complications occurred.

CONCLUSION Whilst the incidence of recurrent laryngeal nerve palsy is comparable to rates in the literature, the incidence of transient palsy is lower than published averages. APS is able to reliably predict recurrent laryngeal nerve palsy based on end amplitude.

KEYWORDS

Thyroid surgery – intraoperative nerve monitoring – Laryngeal nerve

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Introduction

With the routine identification of the recurrent laryngeal nerve (RLN), permanent RLN palsy is rare after thyroid surgery, with published rates ranging from 0.3% to 6%.[1] However, the morbidity associated with RLN palsy is significant and if it occurs bilaterally it can lead to life-threatening airway obstruction. In addition, the rate of temporary palsy following thyroid surgery is still believed to be between 5% and 8%,[2] and the rate of permanent palsy in revision cases can be as high as 14%.[3]

Intraoperative nerve monitoring allows for confirmation of the position of the RLN following dissection and provides feedback on the integrity of the nerve at the end of the procedure. Studies have claimed the use of intraoperative nerve monitoring can reduce the incidence of RLN damage by avoiding accidental transection or clamping.[4] However, it requires visualisation of the RLN and therefore does not help to prevent traction-related injuries during the initial mobilisation phase of thyroidectomy. Indeed, a number of meta-analyses have not shown any difference in the rate of RLN palsy with the use of intraoperative nerve monitoring compared to direct visualisation alone.[5]

The use of continuous intraoperative nerve monitoring (CINM) attempts to address the shortcomings of intraoperative nerve monitoring by providing feedback on the integrity of the nerve throughout the procedure. This is achieved by placing an electrode over the vagus nerve which delivers a periodic 1–2 mA current every two seconds, detected by electrodes placed on the laryngeal muscles via a specialised endotracheal tube (Fig 1).[6] This provides real-time feedback on RLN amplitude and latency and early detection of nerve traction, thus prompting adjustment of surgical technique or cessation of surgery until the RLN signal recovers. By providing feedback on

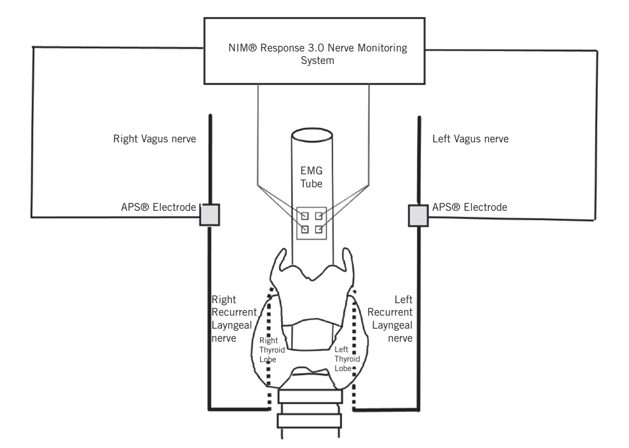

Figure 1 Circuit set-up used for continuous recurrent laryngeal nerve monitoring. An electrode is fitted to the vagus nerve, which transmits a 1–2 mA current. This stimulates laryngeal nerve neuromuscular activity, which is detected by an endotracheal tube with electrodes situated at the level of the glottis. The circuit is displayed on a monitor within the operating room that displays real-time feedback on the amplitude and latency of the signal.

the integrity of the nerve throughout surgery regardless of RLN identification, the likelihood of RLN palsy can also be predicted in every case.

Despite the advantages of CINM, the technique has yet to be widely adopted. Concerns regarding opening the carotid sheath to access the vagus nerve, the potential for complications associated with stimulating the vagus nerve and arguments regarding cost effectiveness have all been reported.[7] However, a number of large studies have demonstrated the safety of this technique and low rates of postoperative RLN palsy in benign cases.[6,8] This study reports on the safety profile of using CINM during thyroidectomy for benign and malignant disease in 256 at-risk nerves. The amplitude and latency of the RLN signal is described with relevance to the incidence of RLN palsy and the sensitivity and specificity of CINM to detect RLN palsy reported.

Materials and methods

To achieve continuous intraoperative nerve monitoring, all patients were intubated with NIM® (Medtronic) electromyogram endotracheal tubes and an APS® (Medtronic) electrode fitted to the vagus nerve on the side to be operated. In brief, a 4–6 cm horizontal neck incision is made and following dissection on to the strap muscles, the sternocleidomastoid muscle is retracted laterally and the carotid sheath opened to expose the vagus nerve. The vagus nerve is stimulated with the hand held probe to confirm nerve function is intact and the APS electrode is gently placed over the nerve using a mosquito clip. The circuit created between the electrodes on the endotracheal tube and APS vagus nerve electrode is recorded using a NIM 3.0 (Medtronic; Fig 1) nerve monitor. This enables the amplitude and latency of the RLN to be continuously monitored intraoperatively for any deviations from the baseline signal recorded at the start of the procedure. At the end of the procedure, the APS electrode is removed and the vagus nerve stimulated with the hand-held probe to confirm intact RLN nerve function. The difference in equipment and cost between CINM and intraoperative nerve monitoring using a modern Medtronic device is the addition of the APS electrode with CINM, which costs £129 per use at the time of writing.

A retrospective review was performed of all thyroidectomies using APS nerve monitoring over a 27-month period between July 2014 and October 2016. Patient age, sex, pathology and type of surgery were recorded from an

Table 1 A mix of benign and malignant disease were treated within the case series with an age range of 21–86 years. Out of malignant cases, papillary thyroid cancer was the most common.

Factor	Patients	
	(*n*)	(%)
Demographics		
Age:		
20–40 years	42	21
40–60 years	100	51
Over 60 years	54	28
Sex:		
Male	27	14
Female	169	86
Pathology		
Benign:		
MNG	46	24
Graves	14	7
Nodule	50	26
Thyroiditis	19	10
Malignant:		
Papillary	39	20
Follicular	16	8
Medullary	5	3
Surgery		
Procedure:		
Hemi-thyroidectomy	110	57
Total thyroidectomy	66	34
Completion thyroidectomy	18	9
Monitored time (mean minutes):		
Left lobe	17.4	
Right lobe	17.8	

online database. The saved APS signal data were used to record the number of times the amplitude and latency fell below baseline, the mean amplitude and latency during the procedure and also total monitoring time. The end amplitude and latency signal were also recorded as being either above or below baseline in 5% increments. Each patient underwent fibreoptic flexible laryngoscopy prior to discharge to assess vocal cord mobility and the outcome of this was recorded from electronic discharge summaries. Resolution of any detected vocal cord paresis was determined by reviewing electronic clinic letters where repeated fibreoptic flexible laryngoscopy was performed. The occurrence of any complications associated with opening the carotid sheath and manipulating the vagus nerve were recorded from the operation note, discharge summaries and clinical follow-up letters.

Results

Over the 27-month period, 194 thyroidectomies were performed using CINM by a single surgeon. Of these 194, 132 were hemi-thyroidectomies and 62 were total thyroidectomies. A total 256 at-risk recurrent laryngeal nerves were therefore monitored using CINM and available for analysis. The indication for surgery was a mix of benign and malignant disease (Table 1). The age range was 27–86 years (mean 52 years) and ratio of male to female was one to six. Mean duration of monitoring was 17 minutes per lobectomy. No complications associated with opening the carotid sheath or manipulating the vagus nerve occurred across all cases.

Permanent RLN palsy occurred in six (2.3%) lobectomies and transient RLN palsy occurred in two lobectomies (< 1%). Of the six with permanent RLN palsy, in one instance the nerve was transected as it was infiltrated by tumour. In the other five cases, the nerve was preserved and in four of these, a signal was achieved at the end of the procedure on stimulating the vagus nerve with the handheld probe. In all cases of RLN palsy, the end amplitude was 50% below the baseline (Table 2). Using an end amplitude of 50% below the baseline, the sensitivity and specificity of CINM to predict RLN palsy was 100% and 85%, respectively (Table 3). When the amplitude was 50% below baseline, the positive predictive value for detecting RLN palsy was 18%, while the negative predictive value when the amplitude was 50% or greater than the baseline was 100%. End latency was less accurate at detecting postoperative vocal fold immobility with a sensitivity of 100% and specificity of 78% when the end latency was 10% or greater above baseline. Intraoperatively, the mean amplitude dropped 50% below baseline more frequently in those with immobile vocal cords postoperatively compared to those with no immobility (unpaired t-test, $P < 0.015$).

Table 2 The start (baseline) and end amplitude and latency are compared across all cases of permanent vocal fold palsy.

Side of palsy	Procedure	Disease	Baseline amplitude (μv)	Baseline latency (ms)	End amplitude (μv)	End Latency (ms)
Left	Total thyroidectomy	Papillary thyroid cancer	322	4.5	5	5.4
Right	Right hemi-thyroidectomy	Benign	1235	2.75	0	2.75
Right	Right hemi-thyroidectomy	Benign	965	3.25	0	5.25
Left	Total thyroidectomy	Papillary thyroid cancer	882	6.38	438	7.66
Right	Total thyroidectomy	Benign	990	3	0	9
Left	Completion thyroidectomy	Papillary thyroid cancer	1234	5.38	10	6.46

Table 3 Evaluation of continuous nerve monitoring to predict recurrent laryngeal nerve palsy postoperatively when the end amplitude was 50% less than baseline.

Amplitude compared to baseline at the end of the procedure	
Above 50% (*n* = 211)	**Below 50% (*n* = 45)**
Number of RLNP in this group (*n* = 0)	Number of RLNP in this group (*n* = 8)
Sensitivity 100%	Specificity 85%
Negative predictive value of detecting RLNP = 100%	Positive predictive value of detecting RLNP = 18%

Discussion

Our rate of permanent RLN palsy using CINM is not significantly lower than average rates published in the literature using intraoperative nerve monitoring.[1] It is important to appreciate that factors can result in RLN palsy that are not influenced by monitoring. For example, in three of the six permanent palsies in our series the recurrent laryngeal nerve was invaded by malignant thyroid tissue, thus making damage to the RLN very difficult to avoid while still achieving complete tumour excision. The role of monitoring in preventing these injuries is therefore limited and a low rate of RLN palsy should be viewed as acceptable in any large series involving a mix of malignant and benign cases.

A reduction in traction injuries is to be expected using CINM as excessive traction of the nerve during mobilisation of the gland is demonstrated on the monitor by a fall in amplitude and rise in latency. This prompts cessation of surgery or an adjustment in surgical technique while the amplitude and latency signal return to baseline. Limiting traction lowers temporary and permanent nerve palsy and we believe this is reflected in the present study's low rate of temporary nerve palsy (< 1%), one which is lower than published rates, ranging between 5% and 8%.[2] Limiting transient palsy rates is desirable as it is associated with delayed recovery, patient anxiety and possible life-threatening airway emergency if bilateral. However, further investigation with a case controlled comparative study is required before definitive conclusions over the role of CINM in reducing temporary RLN palsy can be established.

No complications associated with opening the carotid sheath or manipulating the vagus nerve were recorded in our analysis of 256 at risk nerves. While identification of the vagus nerve within the carotid sheath can be challenging in a small subset of patients with bulky disease, obese necks or scar tissue, the majority of vagus nerves were easily identified in a consistent position using a 6-cm incision. Reports of autonomic instability using CINM have been reported in two small studies involving less than 10 patients.[7,9] The present study, together with other large case series, does not support this finding and it is important to appreciate that the 1–2 mA current used does not evoke a response from the demyelinated C-fibres responsible for problematic autonomic activity.[6]

The ability of nerve monitoring to predict the likelihood of vocal cord paresis has a number of advantages. It can pre-empt possible airway obstruction and allows for targeted early flexible laryngoscopy in those suspected of laryngeal nerve palsy. This study suggests that when amplitude does not fall below 50% of baseline at the end of the procedure than the risk of RLN palsy is low. While intraoperative nerve monitoring is able to assess for intact RLN function at the end of the procedure by direct stimulation of the nerve, the nerve needs to be exposed and false positives are reported in over 5% of cases.[10]

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