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A novel methodology for assessing laryngeal and vagus nerve integrity in patients under general anesthesia

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HIGHLIGHTS

- We present the laryngeal adductor reflex as a new intraoperative monitoring method for laryngeal and vagus nerves.
- This method relies on endotracheal tube electrodes for stimulating and recording laryngeal responses.
- This technique monitors the entire vagal reflex arc, including sensory, motor and brainstem pathways.

ABSTRACT

Objective: To describe a novel methodology for intraoperative neuro-monitoring of laryngeal and vagus nerves by utilizing the laryngeal adductor reflex (LAR).
Methods: Case series of 15 patients undergoing thyroid and cervical spine surgeries under total intravenous general anesthesia. Vocal fold mucosa was electrically stimulated to elicit a LAR using endotracheal tube based electrodes. Contralateral R1 (cR1) and R2 (cR2) responses were recorded using the endotracheal tube electrode contralateral to the simulating electrode.
Results: The LAR was reliably elicited in 100% of patients for the duration of each surgical procedure. Mean onset latency of cR1 response was 22.4 ± 2.5 ms (right) and 22.2 ± 2.4 ms (left). cR2 responses were noted in 10 patients (66.7%). No peri-operative complications or adverse outcomes were observed.
Conclusions: The LAR is a novel neuro-monitoring technique for the vagus nerve. Advantages over current monitoring techniques including simplicity, ability to continuously monitor neural function without placement of additional neural probes and ability to assess integrity of both sensory and motor pathways.
Significance: The LAR represents a novel method for intraoperatively monitoring laryngeal and vagus nerves. The LAR monitors the entire vagus nerve reflex arc and is thus applicable to all surgeries where vagal nerve integrity may be compromised.

1. Introduction

The larynx has a complex neural supply from two different branches of the vagus nerve, the superior laryngeal nerve (SLN) and the recurrent laryngeal nerve (RLN). Afferent sensory input from the supra-glottic and glottic larynx is carried in the internal branch of the superior laryngeal nerve (iSLN), with some overlap from the recurrent laryngeal nerve (RLN) at the glottis. The RLN is the predominant sensory nerve supply for the infraglottic region. The RLN provides the main motor innervation to laryngeal musculature, with the exception of the cricothyroid muscle which is supplied by the external branch of the SLN (eSLN).

Monitoring of RLN, SLN and vagus nerve function is important during surgical procedures where these nerves may be at risk of injury. For thyroid and parathyroid surgeries, the RLN and eSLN lie within the operative field and there have been many recent

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guidelines endorsing the use of intra-operative neuro-monitoring techniques to minimize post-operative neural complications (Randolph et al., 2011; Barczynski et al., 2013; Liddy et al., 2016). The most widely used monitoring technique for the RLN relies on endotracheal tube-based surface electrodes to measure compound muscle action potentials (CMAP) resulting from thyroarytenoid muscle contraction with vocal fold adduction. CMAPs are elicited either via direct RLN stimulation with a hand held neurostimulator probe or indirectly when the nerve is irritated by stretch, compression, etc. More recently, intra-operative stimulation of the vagus nerve proximal to the exit point of the recurrent laryngeal nerve, either intermittently or continuously, has been advocated (Phelan et al., 2012; Schneider et al., 2013).

In the present study, we introduce a novel intra-operative monitoring methodology for assessing the integrity of laryngeal and vagus nerves by utilizing the laryngeal adductor reflex (LAR). The LAR is a protective reflex that prevents aspiration by causing thyroarytenoid muscle contraction and thus vocal fold closure (Sasaki and Suzuki, 1976; Domer et al., 2013). It can be elicited via electrical stimulation of the iSLN (Sasaki et al., 2003; Henriquez et al., 2007) or by stimulation of mechanoreceptors (or other receptors) in the laryngeal mucosa with air puffs (Aviv et al., 1999; Bhabu et al., 2003). More recently, Sulica et al. (2013) elicited the LAR by applying brief electrical stimulation directly to the laryngeal mucosa by a wire electrode passed through the laryngoscope until the mucosa. In awake humans, the LAR consists of early ipsilateral (iR1) and late (R2) bilateral responses and the iR1 response has been shown to be present even during volitional vocal and respiratory tasks, attesting to the primordial and robust nature of this airway reflex (Henriquez et al., 2007). Under general anesthesia, ipsi- and contralateral R1 responses (iR1 and cR1, respectively) have been observed in humans. However, the cR1 response tends to disappear at higher anesthetic levels of halogenated agents (Sasaki et al., 2003).

In this study we introduce a non-invasive, simple and reproducible methodology for eliciting the LAR under general anesthesia that relies solely on endotracheal tube-based surface electrodes. This novel technique monitors not only vocal fold adduction but also the entire vagal reflex arc, incorporating for the first time sensory, motor and brainstem pathways.

2. Patients and methods

2.1. Subjects

Fifteen patients who underwent neck surgery were studied. All participants gave their written, informed consent to laryngeal nerve monitoring. Table 1 shows demographics, diagnosis and type of surgery for each patient. The anesthetic regimen consisted of total intravenous anesthesia (TIVA) using propofol and remifentanil in standard weight based doses.

2.2. Technique

After induction of general anesthesia, the patient was intubated with a Nerve Integrity Monitor TriVantage endotracheal tube (NIM TriVantage™, Medtronics Xomed Inc.; Jacksonville, FL, USA) containing bilaterally imbedded conductive silver ink surface electrodes. These electrodes come into direct contact with the right and left vocal folds (Fig. 1). Following initial intubation, tube position was rechecked and adjusted as necessary using videolaryngoscopy (GlideScope, Verathon Inc. Seattle, WA, USA) after the patient was properly positioned for the neck surgery. For stimulation and recording, an Axon Sentinel 4 EP Analyzer machine was utilized (Axon Systems Inc.; Hauppauge, NY, USA).

The LAR was elicited by electrical stimulation of the laryngeal mucosa on the side contralateral to the operative field using the right or left electrodes attached to the endotracheal tube. A single-stimulus (0.1–1 ms duration) or paired stimuli (ISI 2–4 ms) at intensity up to 4 mA was applied. In order to minimize stimulus artifact two responses elicited by stimuli of reverse polarity were averaged. Surface electrodes ipsilateral to the surgical field (and contralateral to the stimulation side) attached to the endotracheal tube were used to record the contralateral R1 (cR1) and R2 (cR2) responses of the LAR. The cR1 and cR2 responses were defined as the short and long-latency responses, respectively, elicited in the contralateral vocal fold muscles relative to the stimulating side (Fig. 2). Signals were amplified (1000–4000), filtered (bandwidth 1.5–1000 Hz), and stored on the computer for off-line analysis.

In addition to the Axon Sentinel 4 EP Analyzer machine, the endotracheal surface electrodes were connected to the Nerve Integrity Monitor (NIM-Response 3.0 System, Medtronic Xomed, Jacksonville, FL, USA). During all surgeries the NIM machine was simultaneously used for standard monitoring and nerve mapping. A hand-held stimulation monopolar probe (Medtronic Xomed, Jacksonville, FL, USA) was used to deliver current (1–2 mA) to the suspected nerve and was connected to the NIM monitor.

This study was approved by the Institutional Review Board of the Icahn School of Medicine at Mount Sinai hospital.

3. Results

There were three males and twelve females aged between 28 and 84 years (55 ± 20, mean ± SD). In all patients, LARs were suc-

Table 1
Demographics, diagnosis and type of surgery for each patient.

Patient	Gender	Age	Diagnosis	Surgery
1	F	35	Left thyroid goiter	Left thyroidectomy
2	M	50	Thyroid carcinoma metastatic	Total thyroidectomy
3	F	78	Spondylolisthesis C4 and C5	Anterior cervical discectomy and fusion
4	F	80	Hypoparathyroidism	Parathyroidectomy
5	F	28	Thyroid inflammatory disease with thyroid goiter	Total thyroidectomy
6	F	63	Thyroid nodules	Total thyroidectomy
7	F	79	Right thyroid carcinoma	Total thyroidectomy
8	F	70	Right thyroid goiter	Right thyroidectomy
9	F	31	Thyroid goiter	Total thyroidectomy
10	F	49	Thyroid goiter	Total thyroidectomy
11	M	55	Left thyroid nodule	Left thyroidectomy
12	F	35	Right thyroid nodule	Right thyroidectomy
13	M	35	Thyroglossal duct cyst	Excision of left thyroglossal duct cyst
14	F	57	Right thyroid nodule	Right thyroidectomy
15	F	84	Hypoparathyroidism	Parathyroidectomy

M: male; F: female; Age expressed in years.