16 Monitoring ENT Procedures

Denise A. Birkholz and Scott Francis Davis

Introduction

Intraoperative neurophysiological monitoring (IOM) is used during surgeries of the head and neck, procedures to remove tumors of the thyroid, parathyroid, and parotid glands that put cranial nerves at risk, specifically the recurrent laryngeal nerve (RLN) (branch of CNX) and the facial nerve [1]. Monitoring and testing of the cranial nerves at risk accomplishes three goals: (1) to identify the nerve within the surgical field for the purposes of aiding the surgeon in avoiding damage to the nerve during the procedure, (2) to monitor the nerve during the course of the procedure in order to provide real-time feedback to the surgeon about the activity of the nerve, and (3) to provide the surgeon with a prognostic indicator of postoperative nerve function by assessing the stimulation threshold of the nerve at the end of the procedure [2]. These three goals of IOM for ENT procedures contribute to the overall mission of IOM to reduce the incidence of iatrogenic neurological injury. This chapter discusses practical applications of intraoperative monitoring for thyroidectomy, parathyroidectomy, and parotidectomy.

D. A. Birkholz
Neuromonitoring Associates, LLC, Las Vegas, NV, USA

S. F. Davis (✉)
Department of Anesthesiology, Louisiana State University School of Medicine, Tulane University School of Medicine, New Orleans, LA, USA

The Thyroid and Parathyroid Glands

The thyroid gland is one of the largest endocrine glands and is located in the anterior compartment of the neck, inferior to the thyroid cartilage. The thyroid is a butterfly-shaped gland consisting of a right and left lobe connected by an isthmus (Fig. 16.1). Anteriorly, it is covered by the infrahyoid (strap) muscles, and posteriorly, the gland is attached to the cricoid cartilage (just inferior to the thyroid cartilage) and tracheal cartilage. This is why the gland actually moves during swallowing.

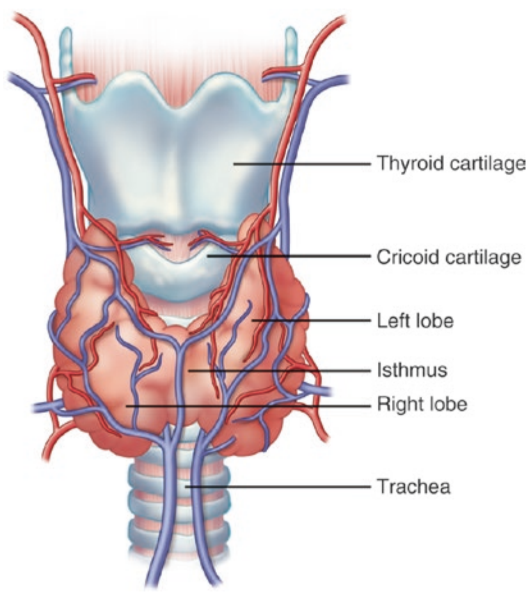

Fig. 16.1 The thyroid gland and surrounding structures

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The thyroid secretes hormones that help regulate the body's metabolism and affect the function of many other systems in the body. Located on the posterior surface of the thyroid are the parathyroid glands. There are typically four parathyroid glands, each about the size of a grain of rice, that are positioned in the upper and lower corners of the lobes on each side of the thyroid. The major function of the parathyroid glands is to secrete parathyroid hormone which maintains serum calcium homeostasis. During thyroidectomy, if parathyroidectomy is not indicated, the parathyroid glands are often saved and explanted into surrounding tissue where they will continue to function.

Thyroidectomy

Removal of the thyroid gland is indicated for a variety of conditions including tumor, goiter, or hyperthyroidism among others. Depending on the pathology, one (hemithyroidectomy) or both (total thyroidectomy) lobes may be removed. To access the thyroid and/or parathyroid glands, a horizontal incision is made across the front of the neck followed by a longitudinal incision through the strap muscles. Division of the local vasculature follows division of the musculature so that the lobes of the thyroid can be mobilized. RLN identification is the first goal of IOM for thyroidectomy and is essential for the purposes of avoiding the nerve during the procedure. Identification of the RLN is only assured when electrical stimulation results in a recorded compound muscle action potential (CMAP) from the vocalis muscle on the EMG recording.

The Recurrent Laryngeal Nerve

The RLN is a branch of the vagus nerve (CNX) that supplies motor function and sensation to the larynx. It innervates all of the intrinsic muscles of the larynx except the cricothyroid muscle, which is innervated by the superior laryngeal nerve (SLN). The RLN branches from the vagus nerve at the level of the subclavian artery on the right and the aortic arch on the left. After looping under the respective artery, the RLN ascends along the tracheoesophageal groove. The paired nerves are named "recurrent" because after branching, they turn back or run in a direction opposite to the vagus nerve. A minority of patients have a nonrecurrent laryngeal nerve branching off the vagus nerve at the level of the cricoid. During surgery, the RLN can be injured in a number of ways: complete or partial transection, traction, compression, misplaced ligature, thermal injury, or ischemia [3]. If the RLN is injured, it can result in temporary or permanent nerve paralysis. If the damage is unilateral, the patient may wake up with hoarseness. If there is bilateral nerve palsy, the airway may be compromised, resulting in dyspnea and in severe cases the need for a tracheostomy. The RLN also provides sensory innervation to the glottis, and a deficit may result in problems swallowing. Rates of injury range from 1% to 8%, with significantly increased risk to the RLN when surgery is for re-exploration, thyroid carcinoma, and total thyroidectomy [3–5]. In addition to thyroid and parathyroid procedures, the RLN is often monitored during ACDF, aortic arch procedures, carotid endarterectomy, and posterior fossa surgeries in order to avoid potential injury due to traction or nerve entrapment between the cuff of the ET tube and the retractor blades [6–8]. The SLN can also be injured during surgery [9, 10]. To monitor the SLN, the surgeon must place electrodes/needles in the cricothyroid muscle [9, 10]. Damage to the SLN results in a monotone voice or inability to change pitch.

RLN Monitoring

Spontaneous and triggered EMG recorded from the vocalis muscle is used to monitor the RLN. During thyroid and parathyroid procedures, it is imperative that two channels are available to monitor both the left and right vocal cords. Endotracheal (ET) tubes with left and right electrodes integrated directly into the tube are commercially available. Alternatively, commercially available adhesive paired electrodes

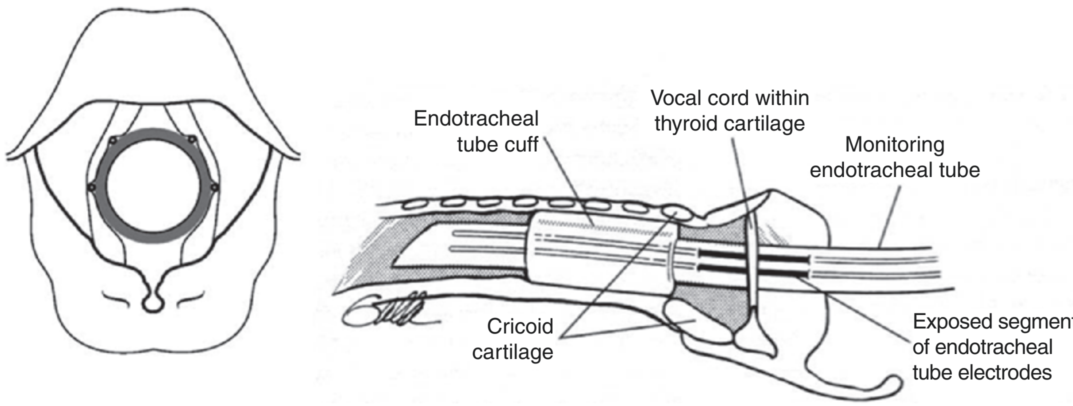

Fig. 16.2 Proper placement of endotracheal tube electrodes

can be attached to standard ET tubes. Proper placement of the electrodes of the endotracheal tube is of critical importance [2, 11, 12] (Fig. 16.2). Early communication with the anesthesia team will greatly aid in confirming proper electrode placement. The neuromonitorist should request a short-acting paralytic for intubation such as succinylcholine and avoidance of lidocaine, as these drugs will impair early recording ability for the purposes of confirming correct electrode placement [2]. Even though the anesthesiologist will be placing the endotracheal tube with electrodes, the monitorist should be knowledgeable about proper placement. It should be emphasized to the anesthesiologist that visual confirmation of the electrodes in contact with the vocal cords is essential. The electrode recording surface is often a blue strip or ring depending on the electrodes used. Common misplacements include electrodes that are too superficial, too deep, or a rotated tube [2].

Unlike EMG from spinal nerve myotomes, baseline EMG recorded from the vocal cords should exhibit baseline activity. Baseline EMG amplitudes of 25–50 μV are most commonly observed with proper electrode placement because the presence of baseline activity is because the vocal cords are contracted at rest and relaxed when speaking. Failure to record baseline activity may be due to a number of factors including misplaced tube, the use of lidocaine, or residual neuromuscular blockade. Asymmetric baseline activity may indicate that the ET tube and electrodes are rotated and not in contact with one side of the vocal cords. Inadequate baseline recordings will prevent proper monitoring during the case and could result in false-negative results. It is important to correct electrode placement if necessary. This is accomplished by asking the anesthesiologist to move the endotracheal tube while the monitorist views the live EMG recording. As the electrodes move into proper position, the amplitude of recorded activity on the screen will increase. The tube depth showing maximal EMG activity should be marked where the tube meets the teeth, and the tube should then be secured. It is not unusual for baseline activity to decrease in amplitude during the procedure as a result of changes in electrode impedance resulting from secretions.

Identification of the RLN is one of the first steps in the thyroidectomy procedure. One technique, called sweeping, is used to aid the surgeon in initial dissection. Monopolar stimulation is used for the sweeping technique. The surgeon is given a handheld monopolar probe and the monitorist will stimulate continuously (at approximately 2 mA) while the surgeon sweeps the field in search of the nerve. The presence of a CMAP response indicates that the nerve is in proximity. There are technical considerations that the monitorist should be aware of during sweeping. The presence of blood or irrigation in the surgical field may shunt current away from the nerve and prevent a response from being seen despite proximity of the nerve to the stimulator [2]. It is therefore important that the surgical field remain dry when stimulating.

The stimulation parameters for sweeping are different than for direct nerve stimulation. The first difference is the use of a monopolar stimulator versus a bipolar stimulator used for direct nerve stimulation. Monopolar stimulation induces a larger current field and is said to be more sensitive than bipolar stimulation. Bipolar stimulation (having the cathode and anode in close proximity) has a smaller current field and while less sensitive is more specific. The stimulation intensity used for sweeping is higher than for direct nerve stimulation. Continuous stimulation up to 3 mA (pulse width not to exceed 50–100 μs) is performed until a response is seen. Once a response is recorded at supramaximal intensity, the intensity is reduced and the threshold for response determined. If there is no current shunting, the stimulation threshold can be used as an indicator of the distance to the nerve. The response should likewise increase in amplitude as the stimulator approaches the nerve.

When the surgeon is ready to confirm the identity of the RLN, direct nerve stimulation is the optimum method [13, 14]. Direct nerve stimulation uses a bipolar stimulator to find the threshold of activation by increasing the intensity of stimulation in 0.1 mA increments starting from 0 mA. The pulse width should not exceed 50–100 μs, and the stimulation intensity should remain <2 mA. A CMAP recorded from the vocal cords with a latency of approximately 2 ms is confirmation of the identity of the RLN (Fig. 16.3). The stimulation threshold at this point can be used as a comparison to values at closing, possibly offering prognostic information to the surgeon on the function of the RLN.

It is possible for the monitorist to not record a response to stimulation even when the surgeon expresses confidence that she/he is stimulating the RLN. There can be several reasons for this apparent discrepancy. The monitorist should immediately work to confirm that there are no technical issues preventing stimulation and recording. As mentioned earlier, the tube must be properly positioned to insure accurate recording, and this can be confirmed by recording of baseline spontaneous activity on both RLN channels. The presence of a stimulation artifact as well as measurement of current return will serve as confirmation of adequate stimulation. Once technical issues are ruled out, attention should turn to nature of the structure being stimulated. If the surgeon reports seeing a response visually within the field, then she/he is most likely stimulating a motor nerve or a muscle directly. Often a visual response without EMG confirmation is due to stimulation of the SLN. If this is suspected, a pair of sterile needle electrodes can be handed off to the surgeon and placed in the cricothyroid muscle and an EMG response recorded. If there is no visual evidence of stimulation, then the surgeon may not be stimulating neural tissue or is possibly stimulating a sensory nerve, which will not produce an EMG response. The monitorist must develop confidence when communicating these possibilities to the surgeon as well as helping the surgeon work through which scenario is most likely.

After identification of the RLN, continuous spontaneous EMG monitoring of the vocal cords is used in order to avoid injury to the nerve.

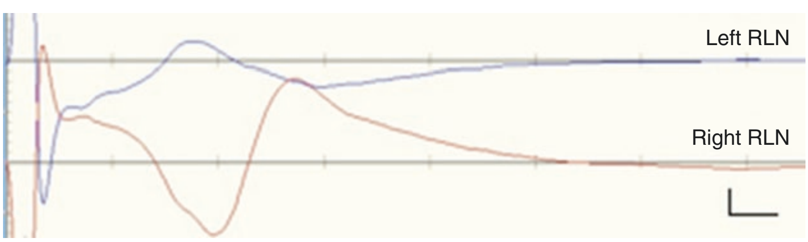

Fig. 16.3 Compound muscle action potential in response to stimulation of the RLN. CMAP recorded from the vocal cords bilaterally in response to stimulation of the right RLN. The stimulation intensity was supramaximal at 2.0 mA, causing the large resultant CMAP to be recorded in both channels. Scale bars indicate 1 ms and 100 μV

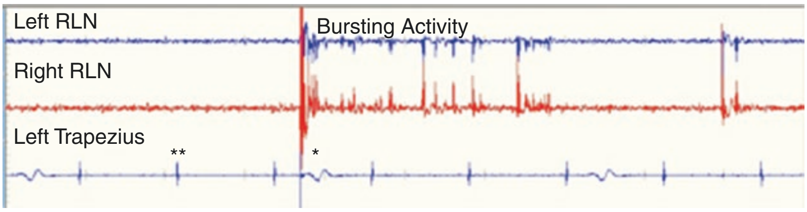

Fig. 16.4 Spontaneous EMG. Baseline EMG activity recorded from the vocal cords bilaterally and the trapezius (as a control). Note the tonic background activity of the RLN channels. Present in this record is bursting activity on the RLN channels. EKG (*asterisk*) and stimulation artifact (*double asterisk*) are seen in the trapezius recording

Spontaneous EMG is best viewed at a time scale of 200 μs/division and display sensitivity of 200 μV/division (Fig. 16.4). Occasional spiking or bursting patterns indicate non-injurious proximity to the nerve while more clinically significant patterns of activity include training and neurotonic discharge. These latter two patterns should be immediately reported to the surgeon. The use of audio EMG is useful in guiding the surgeon during the procedure. The surgeon may appreciate hearing spiking or bursting patterns as he navigates the surgical field. Spontaneous EMG is most useful in detecting impending nerve injury from stretch (retraction) or compression. Complete nerve transection may result in a quick burst of activity followed by electromyographic silence. However, ischemic injury may go completely undetected by EMG monitoring.

Direct stimulation of the RLN at the conclusion of the procedure is recommended to document the function of the nerve. A similar method, such as thresholding used when identifying the nerve, can be used to test the functional integrity of the RLN at closing. Comparable thresholds can be taken as evidence of no new nerve damage during surgery [2].

In addition to intraoperative stimulation and monitoring of RLN function with spontaneous EMG, pre- and postoperative assessment of vocal cord mobility is useful for determining both preexisting pathology and postoperative outcome [2, 15]. The discovery of preoperative hemiparesis is important information that the surgeon and monitorist should consider before proceeding with the procedure. Careful intraoperative monitoring to avoid a bilateral injury is essential.

Parotidectomy

The parotid glands are the largest of the salivary glands, located on either side of the face just inferior and anterior to the ear (Fig. 16.5). Innervation of the parotid glands is by the glossopharyngeal nerve; however, the facial nerve travels directly through the parotid gland on its way to innervate the muscles of facial expression.

The facial nerve emerges from the brainstem between the pons and the medulla. The main function of the facial nerve is motor control of the muscles of facial expression. Extracranially, the facial nerve passes through the parotid gland where it divides into five major branches. This is why it can be said that parotid surgery *is* facial nerve surgery. The parotid glands are a common site of tumor growth and as such may need to be surgically removed. The surgical plane artificially divides the parotid gland into a superficial and deep lobe, with the facial nerve as the dividing line. A superficial parotidectomy will take out the portion of the gland superficial to the nerve plane. A deep lobe, or total, parotidectomy removes both superficial and deep lobes relative to the plane of the facial nerve.

During parotid surgery, facial nerve monitoring can assist the surgeon with functional preservation of the nerve [16]. Spontaneous and triggered EMG of the facial nerve can help to locate and identify the branches of the nerve, warn the surgeon of unexpected stimulation, reduce injury due to retraction and cautery, and evaluate nerve function at the conclusion of the surgery [15]. The five facial nerve branches that pass through the parotid gland are the temporal, zygomatic, buccal, marginal mandibular, and

Fig. 16.5 Parotid gland and facial nerve

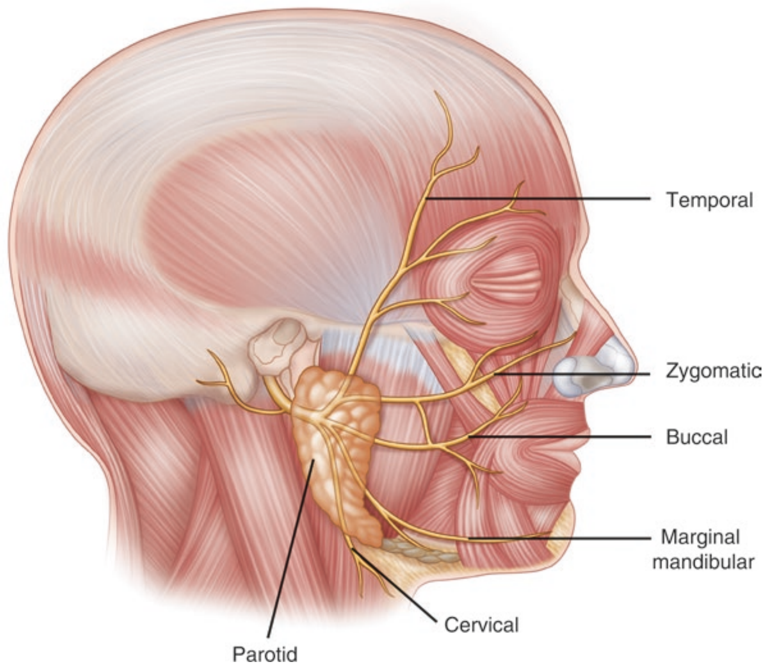

Table 16.1 Branches of the facial nerve and corresponding muscles for EMG

Branch	Muscles
Temporal	Frontalis
	Orbicularis oculi
Zygomatic	Orbicularis oculi
	Nasalis
	Zygomaticus major/minor
Buccal	Buccinator
	Orbicularis oris
Marginal mandibular	Depressor anguli oris
	Depressor labii inferioris
	Mentalis muscles
Cervical	Platysma

cervical. For a parotidectomy, needle electrodes are typically placed in muscles corresponding to at least four out of the five branches (the cervical branch is often not monitored). Muscles commonly used are listed in Table 16.1. Recordings made from the frontalis or orbicularis oculi may be slightly noisier than other channels due to contamination by frontal EEG signals. Stimulation of the facial nerve during surgery assists the surgeon in identifying the facial nerve and distinguishing neural from nonneural tissue. Like RLN monitoring, direct nerve stimulation is the only way to reliably identify the nerve [17]. Typical parameters used are a stimulation intensity of 0.1–2.0 mA with a duration of 50–100 µs [17]. The latency of the facial nerve response when stimulated at the brainstem is approximately 7 ms, but a response when stimulated at the parotid will be shorter, so time base should be adjusted accordingly. The stimulation threshold for the facial nerve should be recorded and compared with stimulation of the nerve following parotidectomy. At closing, functional integrity of the facial nerve can be assessed by stimulating each branch of the facial nerve. Closing stimulation thresholds of <0.5 mA are prognostic for normal postoperative function of the facial nerve [15, 17].

Conclusion

Identification by direct stimulation and continuous monitoring during head and neck procedures helps to reduce injury to cranial nerves. Intraoperative RLN and facial nerve monitoring can provide valuable real-time feedback regarding the location and function of the nerves, thereby decreasing the risk of permanent postoperative damage.

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