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A Novel Means of Clinical Assessment of Laryngeal Nerve Conduction

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Abstract

Introduction—We describe a novel, clinically applicable conduction study of the laryngeal nerves.

Methods—17 normal volunteer subjects were included. Activation of the sensory territory of the superior laryngeal nerve was performed by administration of low level, brief electrical stimulus. The laryngeal closure reflex (LCR) evoked by this stimulus was recorded by needle electrodes. Mean minimal latencies were calculated for each response, and proposed values for the upper limit of normal were determined.

Results—Uniform consistent early ipsilateral responses and late bilateral responses, which exhibit greater variation in latency and morphology, were recorded. Significant side-to-side difference in latencies is observed, consistent with the length discrepancy between right and left recurrent laryngeal nerves.

Discussion—This technique yields clear, quantifiable data regarding neurologic integrity of laryngeal function, heretofore unobtainable in the clinical setting. This study may yield clinically relevant information regarding severity and prognosis in patients with laryngeal neuropathic injury.

Keywords

Laryngeal electromyography; vagus nerve; laryngeal closure reflex; brainstem reflexes; neurolaryngology

Introduction and Background

Normal functioning of the larynx is necessary for breathing, voice production and airway protection during swallowing. Disease or injury resulting in laryngeal dysfunction can have devastating consequences for the affected patient, at times requiring invasive procedures

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such as tracheostomy and/or gastrostomy tube placement, and predisposing the patient to serious pulmonary infections. Further, by limiting a person's ability to communicate and/or eat and drink, these disorders are accompanied by a substantive decrease in quality of life.

Dysfunction of the laryngeal apparatus on the basis of peripheral neuropathic injury is fairly common. Due to the circuitous route of the recurrent laryngeal nerve, this nerve is particularly vulnerable to injury from tumor compression or destruction along its path as a complication of a variety of common surgical procedures, including thyroidectomy, anterior approach to the cervical spine, and cardiac and pulmonary surgery. In addition, idiopathic laryngeal neuropathy, typically in the postviral setting, is a well-recognized clinical entity analogous to Bell's palsy. Yet, no means of directly diagnosing and quantitatively evaluating such nerve dysfunction exists. Clinical assessment depends on endoscopic visualization of the end organ. Although symptom-based therapies to treat these disorders have evolved over the past few decades, identification and quantification of peripheral laryngeal nerve dysfunction remains relatively poor, contributing little to clinical decision-making.

Reflexes involving cranial nerve-brainstem pathways have long been identified and are well-described^{1,2,3}. The corneal/blink reflex, gag reflex, and oculocephalic reflex have important clinical relevance as part of the neurologic examination. A nerve conduction study of the blink reflex (Blink Reflex Study, BRS) was described by Kimura in 1969⁴. This electrodiagnostic study provides quantifiable parameters allowing for evaluation and assessment of the peripheral afferent and efferent limbs of the blink reflex, as well as information regarding relay of this reflex through the central nervous system. Today, this study is performed frequently along with nerve conduction studies and electromyography as a routine component of a clinical electrodiagnostic examination. This study can provide essential information regarding localization and degree of neuropathic injury involving cranial nerves V and VII, as well as provide information regarding relay through the brainstem.

We propose that determination of the electrophysiological parameters of the nerves subserving the larynx will have similar clinical value for diagnosis and prognosis in patients with laryngeal dysfunction. The laryngeal closure reflex (LCR) ensures protection of the airway via bilateral laryngeal adduction resulting in closure of the bilateral vocal folds in response to irritative stimulation of distal laryngeal mucosa. The afferent and efferent limbs of this reflex are subserved by different branches of CN X; the afferent limb by sensory fibers of the superior laryngeal nerve (SLN) and the efferent limb by motor fibers of the recurrent laryngeal nerve (RLN). As with the Blink Reflex Study, it is proposed that deviations from normative values can provide precise localization and information regarding the extent of neurological injury to the larynx, lending greater insight into the mechanisms of laryngeal dysfunction than previously available via current diagnostic tools.

Materials/Methods

This study was approved by the Institutional Review Board of Weill Cornell Medical Center. Healthy adult volunteers with no complaints of voice, swallowing or respiratory problems were recruited from the general population. Using the standard percutaneous

approach used clinically for diagnostic laryngeal electromyography, hookwire EMG electrodes were placed within the bilateral thyroarytenoid muscles. Accurate electrode placement was confirmed by volitional activation of these laryngeal adductors (asking the patient to phonate a sustained /e/). Reference electrodes were positioned over the lateral aspect of the thyroid cartilage on each side, and a ground electrode was placed midline over the superior sternum. The evoked potentials recorded from these muscles were displayed on a dual trace oscilloscope after conventional amplification using a two-channel amplifier (Nicolet Viking 11.2). Following electrode placement, the larynx was visualized by means of a standard flexible laryngoscope inserted transnasally under topical nasal anesthetic, as is done for routine laryngeal evaluation in the office. Activation of the sensory territory of the superior laryngeal nerve was achieved by means of unilateral irritative stimulation to the laryngeal mucosa in the form of a low level, brief electrical stimulus (5-10 mA, 0.1 ms). The stimulus was delivered via a wire electrode passed through the working channel of the laryngoscope. Location of the stimulating electrode was observed endoscopically, and the stimulus was not delivered until placement was confirmed by the endoscopist. The reflex adduction of bilateral vocal folds evoked by unilateral sensory stimulation (LCR) was recorded by needle electromyography. For each subject, a minimum of 4 recordings was obtained from stimulation of each side. The minimal latencies of the responses were marked as agreed upon by two neurologists with fellowship training in clinical neurophysiology and neuromuscular disease.

Results

17 normal volunteer subjects (8 men, 9 women, ages 20-40) were included in the study. Volunteers were in good health, without symptomatic dysfunction of larynx, and with a normal laryngeal examination by laryngoscopy.

Responses were obtained and recorded following right and left sided stimulation of the laryngeal mucosa. This study yields an early response ipsilateral to the side of stimulation (LR1), which is uniform and consistent, and late bilateral responses (ipsilateral LR2 (LR2i) and contralateral LR2 (LR2c)), which exhibit greater variation in latency and morphology (Figure 1).

Mean minimal latencies were calculated for each response (Table 1). Proposed preliminary values for the upper limit of normal (ULN) for these latencies were determined by calculating 3 standard deviations above the mean (Table 2).

Discussion

The presence of an early consistent unilateral response ipsilateral to the side of stimulation and more variable late bilateral responses is analogous to the results seen in the Blink Reflex Study. Extrapolating from the neuroanatomical understanding of the BRS, we postulate that the early ipsilateral LR1 response in this study represents a disynaptic connection between the nucleus solitarius and the ipsilateral nucleus ambiguus in the medulla, whereas the late bilateral LR2 responses are mediated by a polysynaptic pathway between the activated sensory nucleus (presumably the solitary nucleus, although some general afferent vagal

sensory fibers are understood to synapse in the spinal trigeminal nucleus) and the ipsilateral and contralateral nuclei ambiguus.^{4,5,6,7}

The recurrent laryngeal nerve has a unique anatomical feature of significant right to left length disparity due to its embryologically mediated course under the aortic arch on the left, while “recurring” under the subclavian artery on the right. In man, the average difference in length between the right and left recurrent laryngeal nerves is approximately 11 cm (for comparison, right to left differences average 0.8 cm in rat, 13 cm in dog, 30 cm in giraffe).⁸ This is reflected in our data, in that a significant side-to-side difference in LR1 latencies is observed in our study ($p < 0.001$), with longer left LR1 latencies compared with right LR2 latencies, consistent with the longer anatomical pathway the left sided response must travel. Significant lateralized differences were not observed for the LR2 responses, perhaps as a result of polysynaptic relays within the brainstem that may mitigate this difference. It is also possible that the variation of these responses will require that a larger population is studied before a pattern emerges.

This normative data is intended as a foundation for clinical study of patients with laryngeal neuropathies. The current electrodiagnostic assessment of laryngeal neuropathy is limited to electromyography. While capable of demonstrating motor neuropathy, and of establishing whether the nerve is in continuity in cases of trauma, electromyography has proved disappointing in prognostication. Certainly, the absence of motor units and presence of spontaneous activity suggests a lower probability of satisfactory recovery than its opposite. However, the information provided by electromyography is approximate, and complicated by the potential for synkinetic reinnervation from adductor and abductor fibers commixed in the same nerve. In numerous studies, electromyography has not yet proved a reliable guide to clinical treatment.^{9,10,11,12,13,14,15,16,17}

Accurate prognostic information would be invaluable in the selection of treatment of patients with laryngeal neuropathy. For example, treatment of patients with unilateral laryngeal neuropathy consists of procedures aimed at positioning the paralyzed vocal fold in the midline so that the mobile vocal fold may effect glottic closure to prevent aspiration and optimize voice production. Treatment is divided roughly into office-based, minimally invasive but temporary measures and operating-room based open neck procedures which are permanent.^{18,19} The current standard, imposed more by a century's tradition of practice than by any evidence, is to manage patients in expectation of recovery for one year. Prognostic information is of obvious importance in selecting patients for early definitive treatment and sparing them unnecessary and repeated temporary procedures.

In the analogous case of facial neuropathy, electromyography has proven similarly unsatisfactory, yet nerve excitability²⁰, latency²¹, and amplitude of the muscle action potential²² have all been shown to add prognostic information.

In addition to prognostic considerations, electromyography is blind to the afferent nerves. Laryngeal sensory neuropathy has been hypothesized to be critically important in swallowing safety. The only means of assessment is currently the administration of a puff of air via the working channel of a laryngoscope, which is poorly reproducible and non

quantitative, yielding only the presence or absence of the laryngeal closure reflex. By incorporating the afferent arm of the laryngeal closure reflex, the method presented in this paper may yield improved and more consistent data regarding this aspect of laryngeal neural function.

The authors have already embarked on the application of this technique to patients with laryngeal neuropathy, and expect that data from this investigation will help formulate hypotheses and determine the future direction of study.

Conclusions

This technique yields clear, quantifiable data regarding neurologic integrity of laryngeal function, heretofore unobtainable in the clinical setting. This study is well-tolerated and safe, performed in the outpatient setting with the standard diagnostic equipment routinely used by neurologists and otorhinolaryngologists. By enabling the determination of electrophysiological parameters of the nerves subserving laryngeal function, namely the superior laryngeal and recurrent laryngeal branches of CN X, in combination with routine clinical laryngeal EMG, this procedure is expected to provide earlier and more accurate information regarding extent and grade of nerve injury. Because injury grade relates directly to prognosis, the information derived from this test can have immediate clinical relevance in determining optimal treatment of neuropathic injury in patients with dysfunction of speaking, swallowing, and protection of airway.

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Abbreviations

BRS	Blink Reflex Study
LCR	Laryngeal Closure Reflex
LR1	Laryngeal response 1 (early response)
LR2	Laryngeal response 2 (late response)
RLN	Recurrent laryngeal nerve
SLN	Superior laryngeal nerve
ULN	Upper limit of normal

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Figure 1.

Above: Individual Response Tracings

Below: Superimposed Responses

Table 1

Mean Minimal Latencies for Early and Late Responses

Stimulation Side	LR1 Latency Ipsilateral	LR2 Latency Ipsilateral	LR2 Latency Contralateral
Right:	13.2 ms	50.5 ms	50.7 ms
Left :	15.2 ms	52.2 ms	50.6 ms

Table 2

Proposed Upper Limit of Normal (ULN) = 3 SD above mean for Early and Late Responses

Stimulation Side	LR1 Latency Ipsilateral	LR2 Latency Ipsilateral	LR2 Latency Contralateral
Right:	15.6ms	60.6 ms	63.5 ms
Left :	18.8 ms	61.1 ms	62.8 ms