The Laryngoscope

Case Report

Vagal Stimulation and Laryngeal Electromyography for Recurrent Laryngeal Reinnervation in Children

Christen L. Caloway, MD; Gillian R. Diercks, MD, MPH; Gregory Randolph, MD; Christopher J. Hartnick, MD, MPH

Ansa-to-recurrent laryngeal nerve (ANSA-RLN) reinnervation procedures are now often first-line treatments for some children with unilateral vocal fold immobility. Although many describe that children with prolonged denervation and true vocal fold atrophy should not undergo this procedure, there has been no gold-standard means of identifying true denervation. Here, we describe a novel technique using evoked vagal electromyography to predict degree of chronic nerve injury prior to recurrent laryngeal nerve reinnervation in children. This is a simple, readily available technique that may play an important role in predicting likelihood of success with pediatric ANSA-RLN reinnervation.

Key Words: Unilateral vocal fold paralysis, dysphonia, aspiration, ansa reinnervation.

***Laryngoscope*, 00:1–5, 2019**

INTRODUCTION

Various approaches to management have been described for unilateral vocal fold immobility (UVFI) in the pediatric population. Options include injection medialization laryngoplasty (IML), thyroplasty, and ansa-to-recurrent laryngeal nerve reinnervation (ANSA-RLN).[1] ANSA-RLN has emerged over the past decade as an effective option and is gaining popularity.[2–5] A recent survey of the American Society of Pediatric Otolaryngology pediatric laryngology working group revealed that in the setting of a longstanding iatrogenic UVFI, 22% and 37% would offer ANSA-RLN and concomitant IML as a first line therapy in young children and teenagers, respectively.[6] This increasing popularity demands further investigation to determine which patients might most optimally benefit from this procedure.

As the most common etiology of UVFI is iatrogenic surgical injury, the status of the neural circuit is often unknown. Although the incidence of vocal fold immobility following patent ductus arteriosus (PDA) ligation has been reported from 0% to 16%,[7] surgeons often do not know the true status of the nerve following ligation. Even if the nerve is known to be damaged, the nature and durability of that damage is typically unknown. However, this information is critical in determining candidacy for ANSA-RLN to maximize patient outcomes. In the setting of disruption of the neural circuit, vocal fold atrophy is more likely to have occurred and ANSA-RLN more likely to be unsuccessful both in correcting vocal and swallowing problems.

Intraoperative nerve monitoring (IONM) has gained widespread acceptance during thyroid and parathyroid surgery, with vagal electromyography (VEMG) employed as a useful adjunct.[8–10] Schneider et al. reported normative IONM data on children undergoing thyroid surgery, including the impact of age on basal amplitude and latency.[11] To our knowledge, these are the only normative VEMG data available in the literature stratified by age in children. Here, we use the application of VEMG in the chronic injury setting as a new technique offered for better interpretation of neural circuit status.

This is a report of three pediatric patients who underwent ANSA-RLN using VEMG to guide intraoperative decision making. Electromyographic hookwire electrodes (Medtronic, Jacksonville, FL) are inserted into the bilateral thyroarytenoid (TA) and posterior cricoarytenoid (PCA) muscles under direct laryngoscopy (DL) (Fig. 1), and the patient is subsequently taken out of suspension (feeding the wires through the laryngoscope prior to connection to the nerve stimulator) and intubated. Upon identification of the vagus nerve in the carotid sheath at the level of the cricoid, 1 cm of nerve was exposed and intermittently stimulated using a standard Prass probe (Medtronic) at 1.0 mA, and responses were recorded (Figs. 2–4). Amplitudes and latencies were

From the Department of Otolaryngology, Massachusetts Eye and Ear Infirmary, Boston, Massachusetts; and the Department of Otology and Laryngology, Harvard Medical School, Boston, Massachusetts, U.S.A.

Editor's Note: This Manuscript was accepted for publication on May 28, 2019.

Presented as a poster at the American Broncho-Esophagological Association Annual Meeting, Austin, Texas, U.S.A., May 1–5, 2019.

C.L.C. was involved in execution of the study, acquisition of data, analysis and interpretation of data, drafting the article, and final approval of the final manuscript as submitted. G.R.D., G.R., and C.J.H. were involved in planning and execution of the study, as well as the critical review and revision of the manuscript and approval of the final manuscript as submitted. C.L.C. had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

The authors have no funding, financial relationships, or conflicts of interest to disclose.

Send correspondence to Christopher J. Hartnick, MD, Massachusetts Eye and Ear Infirmary, 243 Charles Street, Boston, MA 02114. E-mail: christopher_hartnick@meei.harvard.edu

DOI: 10.1002/lary.28135

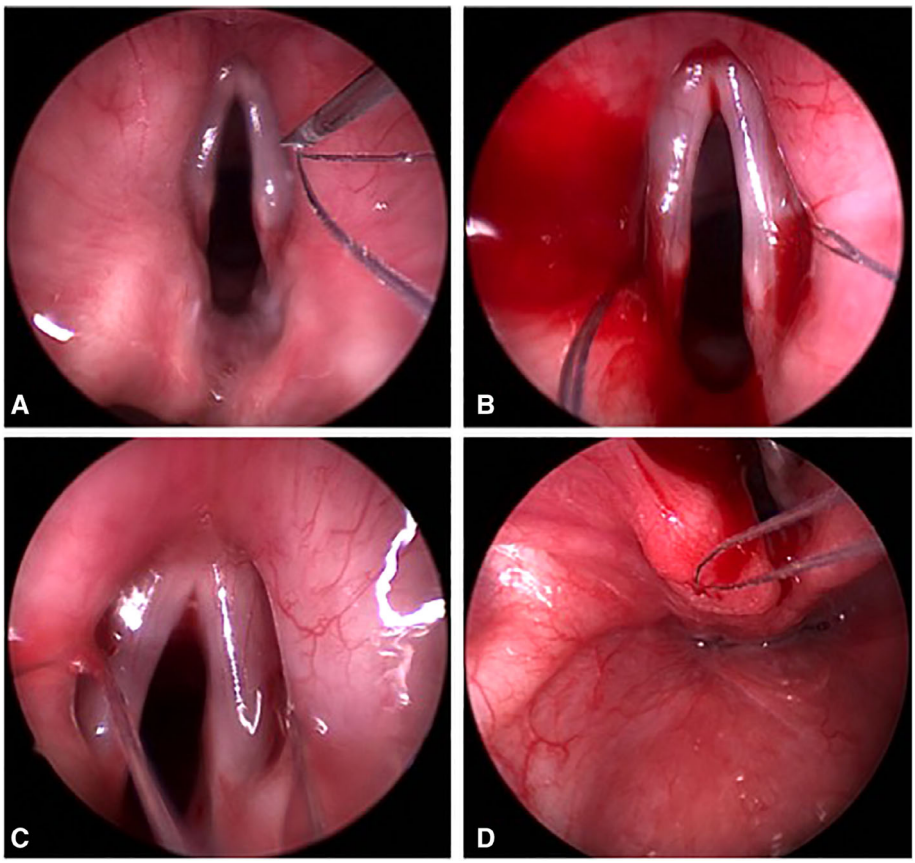

Fig. 1. Hookwire placement (A) in thyroarytenoid (B, C) and posterior cricoarytenoid (D) muscles. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

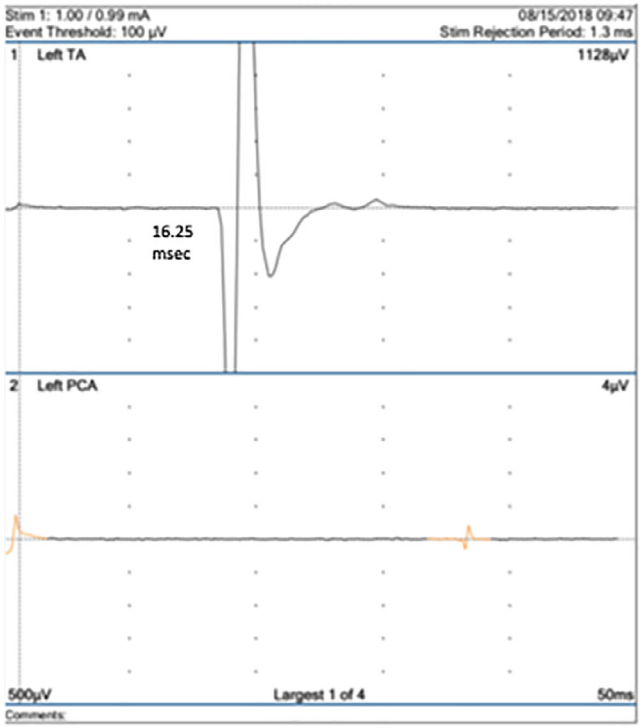

Fig. 2. Evoked vagal electromyography for case 1. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

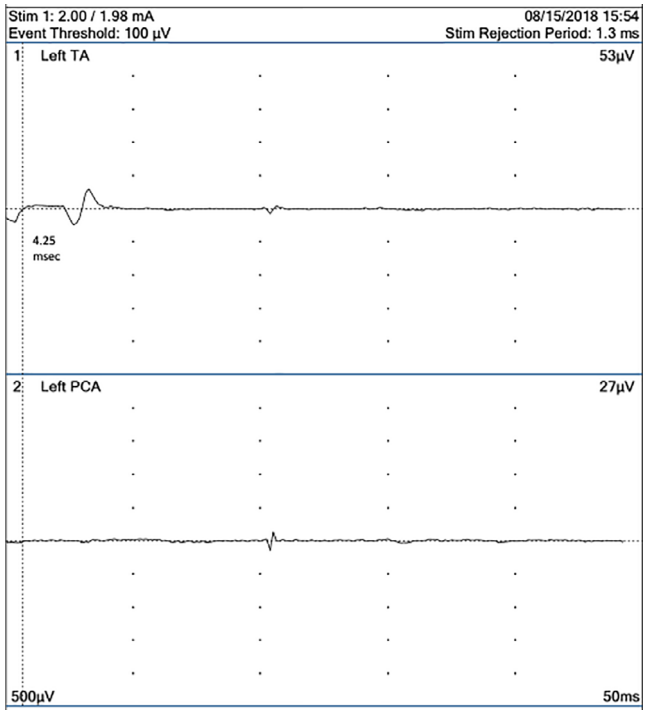

Fig. 3. Evoked vagal electromyography for case 2. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

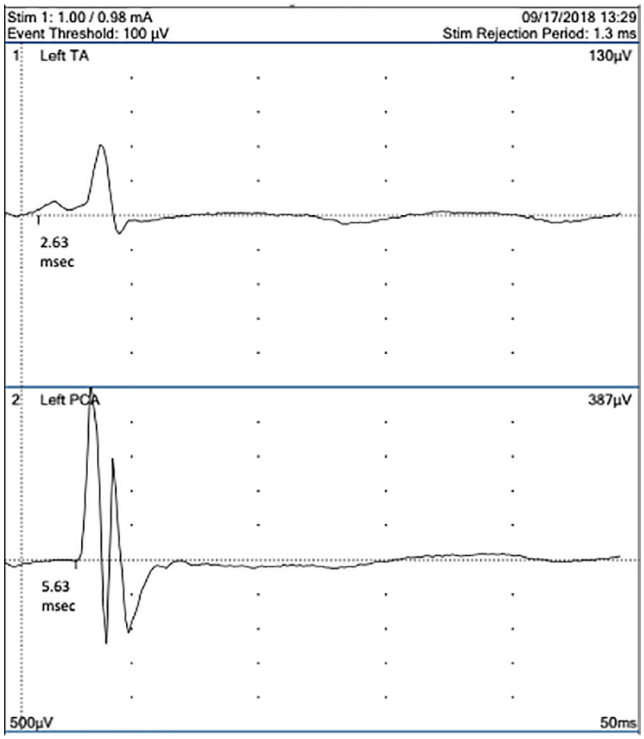

Fig. 4. Evoked vagal electromyography for case 3. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

compared to those reported by Schneider et al.[11] IML was performed with Prolaryn gel (Merz, Raleigh, NC). Vocal outcomes were assessed using the pediatric voice-related quality-of-life questionnaire (PVRQOL),[12] s/z ratio, and maximum phonation time (MPT) when age appropriate. A score of 100 on the PVRQOL demonstrates the best possible perceived quality of life in terms of voice quality and use. Details for cases can be found in Tables I and II.

CASE REPORT

Case 1

This is a 2-year-old female with a history of prematurity and PDA ligation. She presented at 4 months old with hoarseness, feeding difficulties, and left UVFI. A videofluoroscopic swallowing study (VFSS) revealed silent aspiration with thin liquids, and she was started on half-nectar thick liquids. At 10 months old, she underwent DL revealing symmetric true vocal fold (TVF) without atrophy and vertical height mismatch with ipsilateral IML. Postoperatively, she had improvement in her hoarseness but not swallowing. Her parents elected to proceed with neck exploration, VEMG, and possible ANSA-RLN depending upon VEMG findings.

Intraoperatively, the vagus nerve was stimulated, and the amplitude and latency of the VEMG of the ipsilateral TA muscle were 1,128 microvolts and 16 milliseconds, respectively (Fig. 2). The normal amplitude but significantly prolonged latency (Table II) was interpreted to mean that although the neural circuit was intact, it had been damaged during the PDA ligation and thus showed a slowed response. We elected to proceed with ANSA-RLN with IML.

After 6 months, her voice had improved. The preoperative PVRQOL administered to her parents was 51.5, and this had improved to 78.5. The s/z ratio and MPT were unable to be obtained due to patient age. She was cleared for thin liquids following her IML, with 6-month VFSS consistent with no aspiration at any consistency.

Case 2

This is a 14-year-old female with a history of prematurity, PDA ligation, and intubation in the neonatal intensive care unit for 2 months. She presented at 11 years old with hoarseness, choking on thin liquids, and left UVFI. She underwent DL revealing no TVF atrophy nor joint fixation. She also underwent laryngeal electromyography at this time with visible action potentials of the right cord and electrical silence on the left. IML was performed. Postoperatively, she neither had improvement in her hoarseness nor swallowing. Her parents also elected to proceed with possible ANSA-RLN depending on VEMG.

Intraoperatively, the vagus nerve was stimulated, and amplitude and latency of the VEMG of the ipsilateral TA muscle were 53 microvolts and 4.25 milliseconds, respectively (Fig. 3). An intraoperative discussion occurred with the family. Vagal stimulation revealed some, albeit low, amplitude (Table II); therefore, we proceeded with ANSA-RLN with IML rather than aborting to thyroplasty as some neuronal activity existed.

After 6 months, the breathiness of her voice had improved some, but she still reported inability to achieve the loudness she desired. Her PVRQOL actually worsened, falling nearly 12 points. Her s/z ratio at this time was 1.7 (normal 1.0) and her MPT was 8.7 seconds (normal for age >9.0 seconds).[13] She continued to have her baseline level of dysphagia.

TABLE I.
Demographics, Medical, and Surgical History.

Case No.	Gender	Age, yr	Gestational Age, wk	Medical and Surgical History	Age at Injury	Laryngoscopy Findings
1	Female	2	24 weeks	PDA ligation, intubation ×6 weeks, chronic lung disease of prematurity	Birth	Left TVFI, vertical mismatch
2	Female	14	24 weeks	PDA ligation, intubation ×2 months	Birth	Left TVFI, vertical mismatch
3	Male	3	38 weeks	TEF repair, esophageal atresia	Birth	Left TVFI, vertical mismatch

PDA = patent ductus arteriosus; TEF = tracheoesophageal fistula; TVFI = true vocal fold immobility.

TABLE II.
Evoked Vagal Electromyography, Perceptual Voice Function, and Swallowing Function After Reinnervation.

	Case 1	Case 2	Case 3
Amplitude, μV (A-M IQR)[11]	1,128 (320–1,525)	53 (530–1,227)	387 (320–1,525)
Latency, ms (A-M IQR)[11]	16.25 (5.35–6.15)	4.25 (5.20–6.38)	5.63 (5.35–6.15)
Predicted nerve status	Intact	Likely disrupted	Intact
Δ PVRQOL	51.5 to 78.5	66 to 54.5	100 to 90.5
Change in aspiration status	Cleared for thin liquids	None	Cleared for thin liquids

A-M IQR = age-matched interquartile range; PVRQOL = Pediatric Voice-Related Quality of Life.

Case 3

A 3-year-old male born at 38 weeks gestation underwent tracheoesophageal fistula repair at birth and developed left UVFI as well as esophageal atresia. He presented at 13 months old with history of aspiration and left UVFI. He underwent VFSS, which revealed deep penetration with thin liquids and was recommended for half-strength nectar liquids. His parents also elected to proceed with possible ANSA-RLN depending on VEMG.

Intraoperatively, the vagus nerve was stimulated. The hookwire at the ipsilateral TA muscle dislodged, and the VEMG of the PCA muscle was used as a substitute. The amplitude and latency of the VEMG of the ipsilateral PCA were 387 microvolts and 5.63 milliseconds, respectively (Fig. 4). These values fell within the normal range (Table II); therefore, we interpreted this information to mean the neural circuit was intact. We proceeded with ANSA-RLN with IML.

After 6 months, he was swallowing all consistencies safely. His PVRQOL was 100 preoperatively and 90.5 postoperatively. His s/z ratio at this time was 1.49 (normal 1.0) and his MPT was 6.13 seconds (normal for age >6.0 seconds).[13]

DISCUSSION

Here, we present, to our knowledge, the first three cases to use intraoperative VEMG to interpret the status of the recurrent laryngeal nerve circuit prior to ANSA-RLN. This nuanced technique provides surgeons with necessary information to guide intraoperative decision making. Two of our cases demonstrated improvement in aspiration status as predicted, with one of these patients who presented with hoarseness also demonstrating vocal improvement. Case 2 suggests this technique may provide information to predict when an ANSA-RLN procedure may not be successful, thus guiding the surgeon toward thyroplasty. This technique may, therefore, provide additional information to optimize postoperative outcomes in patients with UVFI.

We understand that, in a global view, amplitude relates to the number of fibers participating in an evoked response, and that latency is related to the speed with which that evoked response reaches the larynx. We also appreciate that, postinjury, there are favorable vagal/recurrent laryngeal nerve to ipsilateral reconnections where healthy electromyographic data correspond to near-normal vocal cord motion. In other circumstances, connections are reestablished postinjury but are more synkinetic and, although present, such activity may not be associated with purposeful volitional abduction and adduction. In case 1, we found normal amplitude but prolonged latency. We postulated that the nerve was injured during the PDA ligation but had since reconnected through the injury site. Thus, the number of fibers ramifying to find reconnection was high—thus good amplitude—but the fibers must have been substantially scarred or altered to provide such a slow response (i.e., low latency). These findings contrast to those of case 2, where we found both low amplitude and latency. Unfortunately, case 2 may serve as a benchmark where a value of 50 microvolts in amplitude represents a data point at which reinnervation success is unlikely. Given the greater duration of denervation in this case and her poor outcome, it is possible our findings support those of Smith and Houtz, where a negative correlation existed between denervation duration and vocal outcomes.[14]

We recognize our study included just three cases, limiting its applicability to the complex challenges patients with UVFI present. Furthermore, we collected outcomes in children undergoing both ANSA-RLN as well as IML at 6 months postoperatively, where effects of the IML may still be felt. However, it is the senior author's experience that the injection usually does not provide benefit past 4 months in these cases. Finally, although Schneider et al. used NIM pediatric neuromonitoring tubes, we in the United States are limited to hookwires. Unfortunately, we did experience dislodgment of a hookwire in case 3, necessitating the use of the ipsilateral PCA muscle rather than the TA muscle in this case. However, due to the identical innervation of these two muscles, the PCA serves as a justified substitute. PCA/postcricoid muscle monitoring has been established in a canine model and subsequently shown to be a valid monitoring format in adults.[15]

CONCLUSION

VEMG is a readily available technique that may play an important role in patient selection in pediatric ANSA-RLN. Certainly, larger clinical studies are needed to correlate such testing with long-term vocal and aspiration outcomes and also to develop a construct in which to better interpret VEMG data to predict success of reinnervation.

Acknowledgments

The authors acknowledge Dioan McIlroy for technical support and guidance provided during the execution of this project.

BIBLIOGRAPHY

1. Zur KB, Carroll LM. Recurrent laryngeal nerve reinnervation in children: acoustic and endoscopic characteristics pre-intervention and post-intervention. A comparison of treatment options. *Laryngoscope* 2015;125 (suppl 11):S1–S15.
2. Sipp JA, Kerschner JE, Braune N, Hartnick CJ. Vocal fold medialization in children: injection laryngoplasty, thyroplasty, or nerve reinnervation? *Arch Otolaryngol Head Neck Surg* 2007;133:767–771.
3. Smith ME, Roy N, Houtz D. Laryngeal reinnervation for paralytic dysphonia in children younger than 10 years. *Arch Otolaryngol Head Neck Surg* 2012;138:1161–1166.
4. Smith ME, Roy N, Stoddard K. Ansa-RLN reinnervation for unilateral vocal fold paralysis in adolescents and young adults. *Int J Pediatr Otorhinolaryngol* 2008;72:1311–1316.
5. Zur KB. Recurrent laryngeal nerve reinnervation for unilateral vocal fold immobility in children. *Laryngoscope* 2012;122(suppl 4):S82–S83.
6. Bouhabel S, Hartnick CJ. Current trends in practices in the treatment of pediatric unilateral vocal fold immobility: a survey on injections, thyroplasty and nerve reinnervation. *Int J Pediatr Otorhinolaryngol* 2018;109:115–118.
7. Smith ME, King JD, Elsherif A, Muntz HR, Park AH, Kouretas PC. Should all newborns who undergo patent ductus arteriosus ligation be examined for vocal fold mobility? *Laryngoscope* 2009;119:1606–1609.
8. Sritharan N, Chase M, Kamani D, Randolph M, Randolph GW. The vagus nerve, recurrent laryngeal nerve, and external branch of the superior laryngeal nerve have unique latencies allowing for intraoperative documentation of intact neural function during thyroid surgery. *Laryngoscope* 2015;125: E84–E89.
9. Schneider R, Randolph GW, Dionigi G, et al. International neural monitoring study group guideline 2018 part I: staging bilateral thyroid surgery with monitoring loss of signal. *Laryngoscope* 2018;128(suppl 3):S1–S17.
10. Wu CW, Dionigi G, Barczynski M, et al. International neuromonitoring study group guidelines 2018: part II: optimal recurrent laryngeal nerve management for invasive thyroid cancer-incorporation of surgical, laryngeal, and neural electrophysiologic data. *Laryngoscope* 2018;128(suppl 3): S18–S27.
11. Schneider R, Machens A, Sekulla C, Lorenz K, Weber F, Dralle H. Twenty-year experience of paediatric thyroid surgery using intraoperative nerve monitoring. *Br J Surg* 2018;105:996–1005.
12. Boseley ME, Cunningham MJ, Volk MS, Hartnick CJ. Validation of the pediatric voice-related quality-of-life survey. *Arch Otolaryngol Head Neck Surg* 2006;132:717–720.
13. Mendes Tavares EL, Brasolotto AG, Rodrigues SA, Benito Pessin AB, Garcia Martins RH. Maximum phonation time and s/z ratio in a large child cohort. *J Voice* 2012;26:675.e1–e4.
14. Smith ME, Houtz DR. Outcomes of laryngeal reinnervation for unilateral vocal fold paralysis in children: associations with age and time since injury. *Ann Otol Rhinol Laryngol* 2016;125:433–438.
15. Puram SV, Chow H, Wu CW, et al. Posterior cricoarytenoid muscle electrophysiologic changes are predictive of vocal cord paralysis with recurrent laryngeal nerve compressive injury in a canine model. *Laryngoscope* 2016; 126:2744–2751.