Introduction

Postoperative vocal cord paralysis (VCP) after thyroid and parathyroid surgery remains a challenge, with reported rates as high as 18.6%. While unilateral VCP may compromise a patient’s voice thereby causing occupational disabilities or increased aspiration risk, bilateral VCP is a devastating complication usually requiring tracheostomy. Moreover, recurrent laryngeal nerve (RLN) injury from thyroid and parathyroid surgery is a source of medicolegal liability. Given these risks, intraoperative monitoring (IOM) of the RLN has been increasingly used as a functional electrophysiological assessment of the RLN beyond visual confirmation of RLN structure integrity. IOM is commonly performed with a NIM endotracheal tube, which also allows for postoperative vocal cord EMG monitoring. However, postoperative vocal cord EMG has not been investigated comprehensively, normative values have not been comprehensively reported, and post-cricoid EMG measurements following RLN injury have not been reported.

Post-cricoid EMG monitoring offers a complimentary technique to existing ETT-based monitoring. While loss of any RLN function is reassuring, thyroarytenoid (intrinsic) muscle (PCA) function may be an additional measure of injury severity. PCA monitoring offers a complementary data set in terms of laryngeal anatomy, as the PCA muscle connects the larynx to the cervical spine, in contrast to the RLN, which innervates the thyroarytenoid muscle (Fig. 1). PCA monitoring exclusively measures the depolarization of the PCA muscle, the functional branch of the RLN.

While the present study and previous works suggest the canine model is an appropriate model for studying RLN injury, there are differences in the anatomical and functional patterns relating to EMG measurement of the thyroarytenoid muscle, which differs from the human thyroarytenoid muscle.

The present study and previous work suggest the canine model (where PCA monitoring offers a complimentary data set in terms of laryngeal anatomy, as the PCA muscle connects the larynx to the cervical spine) can be used to evaluate the functional branch of the RLN, which innervates the thyroarytenoid muscle (Fig. 1).

Methods

Posterior cricoarytenoid (PCA) muscle Electrophysiologic Changes are Predictive of Vocal Cord Paralysis with Recurrent Laryngeal Nerve Compressive Injury in a Canine Model

Sidharth V. Puram MD PhD,1 Harold Chow MD,2 Che-Wei Wu MD,2,3 James T. Heaton PhD,4 Dipi Kamani MD,1 Gautham Gorti MD FRCS1,4,5 Feng Yu Chiang MD,1 Gianlorenzo Dionigi MD,1 Marcin Barczynski MD PhD FEBS-ES,6 Rick Schneider MD,1 Henning Drafle MD,4 Kerstin Lorenz MD,4 Gregory W. Randolph MD,4

1Department of Otolaryngology and Head Neck Surgery, Department of Otolaryngology, Massachusetts Eye and Ear Infirmary and Harvard Medical School, Boston, MA; 2Department of Otolaryngology-Head and Neck Surgery, Kaohsiung Medical University Hospital; 3Faculty of Medicine, College of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan; 4Department of Surgery, Massachusetts General Hospital and Harvard Medical School, Boston MA; 5Department of Surgical Sciences and Human Morphology, Division of Surgery, University of Inselsberg - School of Medicine, Vereze, Italy; 6Department of Endocrine Surgery, Jagiellonian University Medical College, Krakow, Poland; 7Department of House Staff Training, Marlin Luther University Halle-Wittenberg, Halle (Saale), Germany; 8Division of Surgical Oncology, Department of Surgery, Massachusetts General Hospital and Harvard Medical School, Boston MA

Objective: Injury to the recurrent laryngeal nerve (RLN) is a documented complication of thyroid and parathyroid surgery. Intraoperative neural monitoring (IONM) has been increasingly utilized to assess the functional status of the RLN. Although the posterior cricoarytenoid muscle (PCA) is innervated by the RLN as the abductor of the larynx, a functional index (EMG) of the PCA has been used to assess RLN injury. However, the correlation between PCA EMG and RLN injury is not documented. The aim of this study was to determine the clinical utility of PCA EMG as a functional index of RLN injury.

Study Design: Single-subject prospective animal study.

Methods: The authors developed a canine model of compressive RLN injury (injury to both RLN) that closely mirrors human physiology and anatom. In this study, postcricoid EMG correlates of post-operative vocal cord paralysis (VCP), postcricoid EMG recordings were obtained before and after compressive RLN injury in association with VCP.

Results: Normative post-cricoid recordings revealed a mean amplitude of 1280 μV (with a maximum of 3741 μV) at 3.5 ms with maximum I (1 ms) RLN stimulation. Following injury, which was associated with VCP in our study, there was a 62.1% decrement in post-cricoid EMG amplitude with maximum RLN stimulation and 90% decrement in minimum RLN stimulation. Threshold stimulation of the vagus was increased by 20% and there was a corresponding 42% decrease in amplitude. For RLN stimulation, latency increased by 17.3% following injury, while threshold stimulation increased by 61% with a 35.5% decrement in EMG amplitude. Thus, if RLN amplitude decreases by ≥80% with an absolute amplitude of ≤300 μV or less and latency increase of ≥10%, then RLN injury is likely associated with VCP.

Conclusion: Our results predict post-operative VCP based on post-cricoid electromyographic IONM and may guide surgical decision-making.

Discussion

Postoperative vocal cord paralysis (VCP) after thyroid and parathyroid surgery remains a challenge, with reported rates as high as 18.6%. While unilateral VCP may compromise a patient’s voice thereby causing occupational disabilities or increased aspiration risk, bilateral VCP is a devastating complication usually requiring tracheostomy. Moreover, recurrent laryngeal nerve (RLN) injury from thyroid and parathyroid surgery is a source of medicolegal liability. Given these risks, intraoperative monitoring (IOM) of the RLN has been increasingly used as a functional electrophysiological assessment of the RLN beyond visual confirmation of RLN structure integrity. IOM is commonly performed with a NIM endotracheal tube, which also allows for postoperative vocal cord EMG monitoring. However, postoperative vocal cord EMG has not been investigated comprehensively, normative values have not been comprehensively reported, and post-cricoid EMG measurements following RLN injury have not been reported.

Post-cricoid EMG monitoring offers a complimentary technique to existing ETT-based monitoring. While loss of any RLN function is reassuring, thyroarytenoid (intrinsic) muscle (PCA) function may be an additional measure of injury severity. PCA monitoring offers a complementary data set in terms of laryngeal anatomy, as the PCA muscle connects the larynx to the cervical spine, in contrast to the RLN, which innervates the thyroarytenoid muscle. Limited prior work has shown similar functional branch assessment may be optimized with the addition of PCA monitoring while an ETT EMG recording is performed.

In particular, we leveraged a canine model of compressive RLN injury, which closely mirrors human physiology and anatom. In this study, postcricoid EMG correlates of post-operative vocal cord paralysis (VCP), postcricoid EMG recordings were obtained before and after compressive RLN injury in association with VCP.

Results: Normative post-cricoid recordings revealed a mean amplitude of 1280 μV (with a maximum of 3741 μV) at 3.5 ms with maximum I (1 ms) RLN stimulation. Following injury, which was associated with VCP in our study, there was a 62.1% decrement in post-cricoid EMG amplitude with maximum RLN stimulation and 90% decrement in minimum RLN stimulation. Threshold stimulation of the vagus was increased by 20% and there was a corresponding 42% decrease in amplitude. For RLN stimulation, latency increased by 17.3% following injury, while threshold stimulation increased by 61% with a 35.5% decrement in EMG amplitude. Thus, if RLN amplitude decreases by ≥80% with an absolute amplitude of ≤300 μV or less and latency increase of ≥10%, then RLN injury is likely associated with VCP.

Conclusion: Our results predict post-operative VCP based on post-cricoid electromyographic IONM and may guide surgical decision-making.

The major problem of human and animal neural monitoring data relates to EMG measurement of the thyroarytenoid muscle, which innervates a laryngeal adductor, through ETT-based electrodes. Currently with ETT IOM, the only way to determine PCA response is through laryngeal twitch assessment. Postcricoid electrode monitoring offers a complementary data set in terms of laryngeal monitoring by measuring depolarization of the PCA muscle, the only laryngeal adductor. Compared to ETT monitoring, PCA electrodes are easily placed and do not require careful gnostic positioning. Aluc PCA electrodes are exclusively designed for laryngeal adductor and thereby provides pertinent data regarding global vocal fold function and improves prediction of postoperative airway patency. The simultaneous measurements of glosus adductor and abductor may provide a new horizon in terms of complete functional branch analysis of the posterior cricoarytenoid muscle branch in patients with these relatively common neural anatomic patterns.

To characterize the electrical signature of a compressed, injured nerve, it is essential to determine normative post-cricoid EMG parameters. Our normative amplitudes are comparable to normative human measurements, suggesting the canine model recapitulates human physiology. In addition, post-cricoid EMG values closely mimic those obtained using ETT IOM monitoring in the canine model.

The present study and previous works suggest the canine model is an appropriate model for studying RLN injury, there are differences in the anatomical and functional patterns relating to EMG measurement of the thyroarytenoid muscle.

While the present study and previous works suggest the canine model is an appropriate model for studying RLN injury, there are differences in the anatomical and functional patterns relating to EMG measurement of the thyroarytenoid muscle.

Our normative amplitudes are comparable to normative human measurements, suggesting the canine model recapitulates human physiology. In addition, post-cricoid EMG values closely mimic those obtained using ETT IOM monitoring in the canine model.

The major problem of human and animal neural monitoring data relates to EMG measurement of the thyroarytenoid muscle, which innervates a laryngeal adductor, through ETT-based electrodes. Currently with ETT IOM, the only way to determine PCA response is through laryngeal twitch assessment. Postcricoid electrode monitoring offers a complementary data set in terms of laryngeal monitoring by measuring depolarization of the PCA muscle, the only laryngeal adductor. Compared to ETT monitoring, PCA electrodes are easily placed and do not require careful gnostic positioning. Aluc PCA electrodes are exclusively designed for laryngeal adductor and thereby provides pertinent data regarding global vocal fold function and improves prediction of postoperative airway patency. The simultaneous measurements of glosus adductor and abductor may provide a new horizon in terms of complete functional branch analysis of the posterior cricoarytenoid muscle branch in patients with these relatively common neural anatomic patterns.

We found remarkable similarities in normative and post injury EMG data during postcricoid monitoring as compared to ETT-based thyroarytenoid monitoring. We found that if post-cricoid EMG amplitude with maximum RLN stimulation decreases by ≥80% with an absolute amplitude of ≤300 μV, combined with a latency increase of ≥10% and stimulation threshold increase ≥20%, then nerve injury and post-operative VCP are probable. We observed post-cricoid EMG IONM may help guide clinical management and help determine the morbidity associated with bilateral thyroid surgery by providing the surgeon with an additional monitoring dataset to ETT-based monitoring systems.