Compound Motor Action Potential Quantifies Recurrent Laryngeal Nerve Innervation

N. K. Bhatt1, A. M. Park1, M. T. Al-Lozi2, R. C. Paniello1
1Washington University, Department of Otolaryngology – Head and Neck Surgery, St. Louis, MO, USA; 2Washington University, Department of Neurology, St. Louis, MO, USA

Abstract

Objective: The compound motor action potential (CMAP) is the summed action potential from multiple muscle fibers activated by a single nerve impulse. For small muscles, it essentially represents the activity of the entire muscle. In this study, the utility of laryngeal muscle CMAP for quantifying innervation following recurrent laryngeal nerve (RLN) injury was investigated.

Method: In a series of canines, both RLNs were exposed 5cm inferior to the cricoid and a stimulating electrode placed. Maximum CMAP amplitudes from the thyroarytenoid (TA) muscles were obtained at baseline and at six months following injury to the RLN. Injury mechanisms included crush, stretch, cautery, and complete transection with reanastomosis.

Results: Prior to injury, baseline CMAP amplitudes averaged 15.8 mV. Immediately following injury, the CMAP dropped to zero in all cases. Six months following injury, average maximum CMAP amplitudes were 16.62 mV (105.1% of baseline) for stretch, 15.6 mV for crush (98.6%), 14.75 mV for cautery (93.3%), and 8.58 mV for transection/repair (54.3%) injuries. These values were approximately correlated with evoked measures of muscle strength.

Conclusion: The CMAP is an accurate measure of RLN innervation of the TA muscle. It may offer advantages over other measures in certain types of laryngeal experiments. The technique could be further developed for clinical applications as well.

Introduction

Vocal fold paralysis is caused by injury to the recurrent laryngeal nerve (RLN), which occurs during head, neck, and thoracic surgery. Inadvertent damage to the RLN during surgery accounts for the largest etiology of vocal fold paralysis. Current clinical measures of vocal fold innervation following injury are limited and not quantitative. Compound motor action potential (CMAP) has not been studied in the setting of RLN injury and vocal fold paralysis. However, CMAP is fundamental in the clinical diagnosis of other neuropathies including brachial plexus injury, spinal cord injury, and spinal muscular atrophy because it accurately quantifies the total motor innervation to a muscle.

CMAP provides advanced characteristics about RLN injury and recovery that cannot be measured from established methods. Figure 1 illustrates important measurements derived from CMAP. CMAP is quantitative, providing a measure of total RLN innervation. CMAP is an evoked potential – derived from the total muscle contraction. CMAP may be a better measure of total vocal fold innervation helping clinical decision-making and evaluating experimental RLN regeneration strategies. In this study, we present a novel method to quantitatively measure vocal fold innervation following injury using CMAP.

Figure 1: A. Onset latency represents the time between RLN stimulation and the beginning of muscle contraction. This is measured in milliseconds. B. The peak amplitude measured in millivolts quantifies the maximum contractile strength. C. The area under the curve equals the summation of all motor unit action potentials.

Method

Experimental Details:

1. Twenty-one canine hemilyrngal preparations were divided into four experimental groups (Table 1).
2. Protocol approved by Washington University’s Institutional Animal Care and Use Committee (IACUC).

Procedure:

1. Tracheotomy was performed and RLN were exposed through anterior neck incision 5cm inferior to the cricoid.
2. Stimulating electrode placed on RLN and receiving electrode placed within TA muscle. Baseline CMAP amplitude measurement performed.
3. RLN injured either by stretch (n=5), crush (n=3), cautery (n=4), or transection/repair (n=9) in a standard fashion in order to diminish CMAP amplitude.
4. Repeat CMAP measurement repeated at 6 months following surgery. Figure 2 details the study design used to measure CMAP recovery.

Introduction

Hemilyrngal procedures included stretch (n=5), crush (n=3), cautery (n=4), and transection/repair (n=9) in a standard fashion in order to diminish CMAP amplitude.

Figure 2: Experimental procedure for measuring CMAP recovery. Baseline CMAP performed prior to RLN injury. Each injury mechanism resulted in a diminution of CMAP amplitude to 0mV, noted by no positive deflection of the CMAP curve. Recovery CMAP was measured 6 months following RLN injury.

Discussion

Our results suggest that CMAP can measure the degree of vocal fold innervation following RLN injury. Paniello et al. previously reported canine RLN recovery following injury using laryngeal adductory pressure (LAP). In this previous work, the transection/repair injury demonstrated worse LAP recovery (56%) compared to cautery or crush (65% and 105% respectively), consistent with the results of this study. The CMAP recovery appears to correlate with the severity and mechanism of RLN injury. The transection/repair causes the greatest reduction in CMAP recovery.

There are two significant applications of using CMAP to measure vocal fold innervation. First, investigations measuring the efficacy of experimental RLN regeneration techniques like incorporating stem cells, growth factors, and nerve grafts would benefit from a quantitative tool to accurately measure total laryngeal innervation. Second, in the clinical setting, CMAP may allow practitioners to better treat patients with vocal fold paralysis. A quantitative measure of RLN innervation can help determine if performing a destructive procedure, like ansa cervicalis-to-RLN anastomosis, would be beneficial or counter-productive. Clinicians could better estimate the functionality of the RLN following injury since total innervation would be known.

Conclusions

1. Stretch, crush, cautery injuries to the RLN resulted in better recovery of the RLN compared to transection/repair injury. Transection/repair injury resulted in the least recovery of CMAP amplitude.
2. CMAP is a quantitative measure of total vocal fold innervation. Therefore, this technique may provide a better measure of vocal fold innervation compared to existing methods clinically and experimentally.

Table 1. CMAP recovery data. The baseline CMAP amplitude was 15.8mV. P values are based on comparison with baseline (pre-injury) CMAP amplitude using 2-tailed t-test. NS = not significant

<table>
<thead>
<tr>
<th>Group</th>
<th>RLN Injury Mechanism</th>
<th>CMAP amplitude at recovery</th>
<th>% of baseline recovery</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Stretch (n=5)</td>
<td>16.62 mV ± 3.13</td>
<td>105.11%</td>
<td>NS</td>
</tr>
<tr>
<td>B</td>
<td>Crush (n=3)</td>
<td>15.6 mV ± 2.49</td>
<td>98.66%</td>
<td>NS</td>
</tr>
<tr>
<td>C</td>
<td>Cautery (n=4)</td>
<td>14.75 mV ± 2.91</td>
<td>93.28%</td>
<td>NS</td>
</tr>
<tr>
<td>D</td>
<td>Transection/Repair (n=9)</td>
<td>8.58 mV ± 2.99</td>
<td>54.25%</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

References


Contact

N. K. Bhatt
Washington University, Department of Otolaryngology – Head and Neck Surgery
St. Louis, MO
Email: bhattn@ent.wustl.edu
Website: http://oto.wustl.edu/