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RESEARCH PAPER

# Recovery from rocuronium-induced neuromuscular block was longer in the larynx than in the pelvic limb of anesthetized dogs

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## Abstract

**Objective** To determine if neuromuscular monitoring at the pelvic limb accurately reflects neuromuscular function in the larynx after administration of rocuronium in anesthetized dogs.

**Study design** Prospective experimental study.

**Animals** Six healthy Beagle dogs.

**Methods** Anesthesia was maintained in dogs with isoflurane and a continuous infusion of dexmedetomidine. Rocuronium (0.6 mg $kg^{-1}$) was administered intravenously to induce neuromuscular block. Train-of-four (TOF) impulses were applied to the left recurrent laryngeal nerve (RLn) and the peroneal nerve (Pn). The evoked TOF ratio (TOFR; T4:T1) was measured with electromyography (EMG) simultaneously at the larynx and at the pelvic limb. Spontaneous recoveries of T1 to 25% ($T1_{25\%}$) and 75% ($T1_{75\%}$) of twitch height, and to TOFR of 0.70 and 0.90 ($TOFR_{0.90}$) at each EMG site were compared.

**Results** Data from five dogs were analyzed. Times to $T1_{25\%}$ were similar at the pelvic limb and larynx when measured by EMG; time to $T1_{75\%}$ was slower at the larynx by $6 \pm 4$ minutes ($p = 0.012$). The larynx had a slower recovery to $TOFR_{0.70}$ ($41 \pm 13$ minutes) and $TOFR_{0.90}$ ($45 \pm 13$ minutes) than did the pelvic limb [$29 \pm 8$ minutes ($p = 0.011$) and $33 \pm 9$ minutes ($p = 0.003$), respectively]. When the pelvic limb EMG returned to $TOFR_{0.70}$ and $TOFR_{0.90}$, the larynx EMG $TOFR_{0.70}$ and $TOFR_{0.90}$ values were $0.32 \pm 0.12$ ($p = 0.001$) and $0.38 \pm 0.13$ ($p = 0.001$), respectively.

**Conclusions and clinical relevance** After administration of rocuronium, neuromuscular function assessed by EMG recovered approximately 36% slower at the larynx than at the pelvic limb. The results in these dogs suggest that quantitative neuromuscular monitoring instrumented at a pelvic limb may be unable to exclude residual block at the larynx in anesthetized dogs.

***Keywords*** airway obstruction, aspiration, complication, monitoring, residual paralysis.

## Introduction

Residual neuromuscular block is the term used to describe the incomplete recovery of neuromuscular transmission in the postoperative period following the use of a neuromuscular blocking agent (NMBA). The incidence of residual neuromuscular block in humans has been reported to range between 2% and 64%, depending on the methods used, the NMBA administered and whether pharmacological reversal has been used (Murphy & Brull 2010). Residual paralysis has been associated with adverse respiratory events, such as postoperative hypoxemia and/or upper airway obstruction (Murphy et al. 2008a).

In humans, the incidence of residual paralysis and its associated complications can be decreased with quantitative monitoring of neuromuscular function (Murphy et al. 2008b). Quantitative monitoring in a clinical setting is usually performed with electromyography (EMG) or acceleromyography (AMG). These monitors are available commercially and have been used previously in dogs (Sakai et al. 2015). However, neuromuscular monitoring evaluates the status of a



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single nerve—muscle group and that information is frequently extrapolated to the entire skeletal musculature. Ideally, information about neuromuscular function obtained at one site should reflect the status of all motor units in the patient, or at least reflect the neuromuscular status of other nerve—muscle groups of clinical importance. However, the duration of neuromuscular block of distinct muscles is different (Ibebunjo & Hall 1994) and this discrepancy might differ between species. Return of laryngeal function is particularly important in the postoperative period, because both laryngeal adduction (to prevent aspiration) and abduction (for airway patency) require active laryngeal muscles. If return of neuromuscular function in the larynx were to lag behind that in the limb, results obtained from a limb might prompt premature removal of airway support and contribute to postoperative aspiration, hypoxemia and/or upper airway obstruction. In this investigation we measured the recovery time from rocuronium-induced neuromuscular block at the pelvic limb (one of the conventional sites of monitoring) and at the larynx in anesthetized dogs (site of clinical importance).

The primary aim of this study was to compare recovery from rocuronium neuromuscular block at the pelvic limb and at the larynx by monitoring neuromuscular function using EMG. Concurrent measurements with AMG were obtained, as this technique is probably the most commonly used technique for quantitative neuromuscular monitoring in a clinical setting. We hypothesized that neuromuscular function returns faster at the pelvic limb than at the larynx after administration of rocuronium in anesthetized dogs.

## Materials and methods

This investigation was approved by the Institutional Animal Care and Use Committee of Cornell University. Six healthy (based on regular physical examination and hematology) adult Beagle dogs were included. These dogs were participating in an unrelated research project that involved the surgical exposure of the left recurrent laryngeal nerve (RLn). The six intact female dogs were aged [mean ± standard deviation (SD)] 1.4 ± 0.2 years and weighed 7.4 ± 0.6 kg.

Food but not water was withheld overnight prior to anesthesia. Each dog was administered dexmedetomidine (2 μg $kg^{-1}$; Dexdomitor; Pfizer Animal Health, NY, USA) and buprenorphine (20 μg $kg^{-1}$; Buprenex; Reckitt Benckiser Pharmaceuticals Inc., VA, USA) through a catheter in a cephalic vein. Anesthesia was induced with propofol (2 mg $kg^{-1}$; PropoFlo; Abbott Laboratories, IL, USA) administered intravenously (IV). An EMG-capable tracheal tube (NIM EMG endotracheal tube; Medtronic Xomed, FL, USA) was inserted orally, and the cuff was inflated and connected to a rebreathing circle system (Ohmeda Modulus SE; GE Healthcare, WI, USA). Anesthesia was maintained with isoflurane (Forane; Arkema Inc., PA, USA) in oxygen at an end-tidal isoflurane concentration ($F_E'$Iso) of 1.3—1.5%. Dexmedetomidine (2 μg $kg^{-1}$ $hour^{-1}$) was infused IV (Medfusion 3500; Smiths Medical ASD Inc., MN, USA). The lungs were ventilated mechanically (Ohmeda 7900; GE Healthcare) to maintain the end-tidal carbon dioxide tension ($P_E'CO_2$) at 35—45 mmHg (4.7—6.0 kPa). A balanced electrolyte solution (5 mL $kg^{-1}$ $hour^{-1}$; Plasma-Lyte A; Abbott Laboratories) and meloxicam (0.2 mg $kg^{-1}$; Metacam; Boehringer Ingelheim Vetmedica, Inc., MO, USA) were administered IV. Monitoring during anesthesia included continuous electrocardiography, hemoglobin oxygen saturation ($SpO_2$), $P_E'CO_2$, $F_E'$Iso, oscillometric noninvasive arterial pressure (neonatal size 3, placed above one carpus; 3 minute duty cycle) and rectal temperature (Cardell Touch; Midmark Corp., OH, USA). Temperature was maintained at 38—39 °C with a forced-air warming device. Dogs remained in dorsal recumbency for the duration of anesthesia.

### Neuromuscular monitoring with EMG at the larynx

After clipping and aseptic preparation of the skin, a lateral approach to the larynx was made in a standard fashion ventral to the right linguofacial vein. The subcutaneous fascia was divided bluntly and the RLn identified, running on the caudolateral aspect of the cricoid cartilage, and a cuff electrode (2 mm diameter, MED-EL; Ardiem Medical Inc., PA, USA) was placed around the left RLn. The ground electrode of the EMG tracheal tube was placed on the dog's forehead. Supramaximal current (1—3 mA; Model 2100 Isolated Pulse Stimulator; A-M Systems, WA, USA) was applied to the RLn though the cuff electrode in a train-of-four (TOF) pattern (2 Hz, 0.2 ms pulse duration) repeated every 15 seconds throughout the experiment. Three consecutive, indirectly evoked TOF electromyograms were stored (computer files recorded with Sierra Wave; Cadwell Laboratories, Inc., WA, USA) every 2 minutes throughout the experiment for *post hoc* measurement. Stimulation of the RLn produced an EMG signal that was detected by the electrodes on the tracheal tube (Fig. 1a); an artifact (representing the stimuli) followed





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