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RESEARCH PAPER

Partial neuromuscular block impairs arytenoid abduction during hypercarbic challenge in anesthetized dogs

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Abstract

Objective To evaluate the effect of two levels of partial neuromuscular block (NMB) on arytenoid abduction, tidal volume (V_T) and peak inspiratory flow (PIF) in response to a hypercarbic challenge in anesthetized dogs.

Study design Prospective laboratory study.

Animals Eleven healthy male Beagle dogs aged 3–5 years.

Methods Dogs were anesthetized with propofol and dexmedetomidine infusions. The rima glottidis was observed via an endoscope placed through a laryngeal mask airway. Atracurium infusion was titrated to obtain two levels of partial NMB. The normalized glottal gap area (NGGA; glottal gap area normalized to height squared of rima glottidis) at peak inspiration during a hypercarbic challenge (10% CO_2 inspired for 1 minute) was measured at baseline, during mild [train-of-four (TOF) ratio 0.4–0.6] and shallow (TOF ratio 0.7–0.9) NMB, and 30 minutes after spontaneous recovery from NMB. The V_T and PIF were measured at the same time points and compared using ANOVA for repeated measures and Tukey's *post hoc* tests.

Results The NGGA and V_T were significantly lower than baseline during both levels of partial NMB with no difference between mild and shallow NMB ($p < 0.05$). They returned to baseline values after spontaneous recovery from NMB. PIF was not altered significantly during partial NMB.

Conclusions and clinical relevance The NGGA and V_T at peak inspiration in response to a hypercarbic challenge were reduced during partial NMB block, with decreased abduction of the arytenoid cartilages. This dysfunction was present even at shallow levels of NMB.

Keywords Atracurium, carbon dioxide, larynx, neuromuscular blocking agent.

Introduction

Residual neuromuscular block (NMB) is frequently encountered after general anesthesia in humans, and is associated with an increased incidence of adverse postoperative respiratory events, such as hypoxia (Murphy 2006). In humans, the ventilatory response to hypoxia is blunted in the presence of partial NMB (Murphy & Brull 2010), and the ability to swallow and protect the larynx and airways from foreign material is impaired, even at modest levels of partial NMB (Eriksson et al. 1997; Sundman et al. 2000). Mild degrees of partial NMB, measured at the adductor pollicis in humans, can affect the ability to maintain a patent upper airway (Herbstreit et al. 2009), and an association between residual NMB and upper airway collapse has been reported (Murphy 2006; Eikermann et al. 2007).

The effects of NMBA vary among muscles that maintain a patent airway during inspiration (Donati et al. 1991; Ibebunjo et al. 1999; Lu et al. 2010). The cricoarytenoid dorsalis (CAD) muscles are the sole abductors of the arytenoid cartilages and are responsible for increasing the cross-sectional area of the rima glottidis (Brancatisano et al. 1984; Sanders et al. 1993). Dysfunction of the CAD caused by partial NMB might affect the ability to maintain a patent airway and could negatively affect inspiration.

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The objective of this investigation was to evaluate the effect of two levels of partial NMB on the ability to abduct the arytenoid cartilages and vocal cords in response to a hypercarbic challenge in anesthetized dogs. We hypothesized that partial NMB would reduce arytenoid abduction in response to the hypercarbic challenge and that normal arytenoid abduction would be restored after neuromuscular function had returned, as measured at a limb with acceleromyography (AMG). In addition, that tidal volume (V_T) and peak inspiratory flow (PIF) would be reduced during partial NMB and would return to baseline upon restoration of neuromuscular transmission.

Materials and methods

This study was performed in accordance with the Public Health Service Policy on Humane Care and Use of Laboratory Animals, the NIH guide for Care and Use of Laboratory Animals, and was approved by the Cornell University Institutional Animal Care and Use Committee (no. 2011-0054).

Animals

Eleven healthy male Beagle dogs from a research colony, aged 3–5 years and weighing 7.2–14.5 kg, were evaluated. Animals were housed individually in the research unit facility, observed daily and underwent physical examinations regularly. Food, but not water, was withheld overnight prior to general anesthesia. ARRIVE guidelines for reporting *in vivo* experiments were followed throughout (Kilkenny et al. 2012).

General anesthesia and instrumentation

A catheter (20 gauge; Monoject; Covidien LLC, MA, USA) was aseptically placed in a cephalic vein. The dog was administered glycopyrrolate (4 μg kg^{-1}; Baxter Healthcare Corp., IL, USA) subcutaneously and metoclopramide (0.5 mg kg^{-1}; Hospira Inc., IL, USA) intravenously (IV). General anesthesia was induced with dexmedetomidine (2 μg kg^{-1}; Putney Inc., ME, USA) IV and propofol (2 mg kg^{-1}; Actavis Pharma Inc., NJ, USA) IV, and maintained with a propofol target controlled infusion (5.4–8.6 μg mL^{-1}; CCIP Program, Version 3, Department of Anaesthesia and Intensive Care, Chinese University of Hong Kong) and dexmedetomidine (1 μg kg^{-1} $hour^{-1}$; Medfusion 3500; Smiths Medical ASD, Inc., MN, USA). The target plasma concentration of propofol was initially adjusted to prevent purposeful movement and autonomic responses to peripheral nerve stimulation; that target concentration was unchanged thereafter. A laryngeal mask airway (LMA, size 2.5–5.0; AES, WA, USA) was inserted orally and connected by a three-way adaptor to a Bain nonrebreathing circuit (CPRAM Circuit; Teleflex Medical, NC, USA). The dog breathed 100% oxygen spontaneously (oxygen inflow 4 L $minute^{-1}$). Monitoring included an electrocardiogram, oscillometric noninvasive blood pressure measurement, pulse oximetry, capnography and rectal temperature (RT) (Cardell Touch Veterinary Monitor; Midmark, NY, USA). The RT was maintained at 36–38 °C using a heated table. Lactated Ringer's solution (2.5 mL kg^{-1} $hour^{-1}$; Hospira Inc., IL, USA) was infused IV during anesthesia.

The PIF was measured using a respiratory monitor (NICO2; Novametrix Medical Systems, Inc., CT, USA) connected to the LMA and recorded using data acquisition software (LabChart; ADInstruments, New Zealand). V_T was derived from the acquired flow signal.

Laryngeal endoscopy

A high-definition videoscope (3 mm diameter, FLEX-Xc; Karl Storz Veterinary Endoscopy, Germany) was introduced through the free port of the three-way adaptor into the LMA and advanced until rostral to the larynx. The videoscope was positioned to achieve a Brimacombe score of 3 (vocal cords and dorsal aspect of epiglottis visible) or 4 (vocal cords visible) (Brimacombe & Berry 1993). A flexible, non-traumatic stylet (2 mm diameter) was placed alongside the videoscope and positioned immediately rostral to the arytenoid cartilages, to be used for spatial calibration during measurements (Cheetham et al. 2015). Care was taken to avoid contact between the stylet and the arytenoid cartilages. Once the desired image was captured, the port was sealed and the endoscope fixed in place using dental impression material to prevent movement.

Peripheral neuromuscular monitoring

The dog was placed in sternal recumbency with the abdomen rotated so that both pelvic limbs extended laterally to the same side. The uppermost pelvic limb was supported almost parallel to the table, allowing free movement of the tarsus. This limb was used to measure neuromuscular transmission using AMG (TOF-Watch SX; Organon Ltd., Ireland). The common fibular nerve was stimulated using

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