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RESEARCH PAPER

Differences between acceleromyography and electromyography during neuromuscular function monitoring in anesthetized Beagle dogs

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Abstract

Objective Quantitative neuromuscular monitoring is essential for studies of potency and duration of neuromuscular blocking agents, and for detecting residual paralysis in anesthetized patients. This investigation evaluates whether there are systematic differences between acceleromyography (AMG) and electromyography (EMG); two quantitative methods for monitoring neuromuscular block.

Study design Prospective.

Animals Ten healthy Beagle dogs.

Methods Dogs were anesthetized with isoflurane and dexmedetomidine. Both ulnar nerves were stimulated with a train-of-four (TOF) pattern every 15 seconds. The magnitude of the first twitch (T1) and the TOF ratio (magnitude of T4/T1; TOFR) were quantified simultaneously with AMG and EMG, applied randomly to each extremity. The extent of maximal block (T1 depression) and onset time were measured by AMG and EMG during TOF monitoring after the administration of cisatracurium (0.05 mg kg^{-1}). In addition, recovery of T1 to 25% and 75%, the recovery index (time between T1 of 25% and 75%), and recovery of the TOFR to 0.9 were used to characterize recovery from cisatracurium and were compared between monitors. Regression and Bland-Altman plots for T1 and TOFR were also created.

Results Maximal block and onset time were not different between monitors. Time to recovery of T1 to 25% and 75%, and time to TOF ratio 0.9 was significantly shorter with AMG. The recovery index was not different between monitors. When the TOFR returned to 0.9 with AMG, EMG still measured considerable residual block (TOFR 0.47).

Conclusions and clinical relevance Electromyography consistently detected residual NMB when recovery from NMB was complete as assessed by AMG.

Keywords cisatracurium, dog, neuromuscular block, residual paralysis.

Introduction

The presence of residual neuromuscular block (NMB) during recovery from general anesthesia is a commonly overlooked complication; approximately 40% of humans recover from anesthesia with incomplete neuromuscular function (Murphy & Brull 2010). This is important because even a small amount of residual NMB increases the incidence of postoperative respiratory complications, such as hypoxia and upper airway obstruction in people (Murphy et al. 2008). The incidence of residual

blockade is substantially reduced when objective monitoring of neuromuscular function is used in horses and in people (Martin-Flores et al. 2008; Murphy et al. 2011). Objective measurement of neuromuscular transmission is also crucial to most of the controlled pharmacodynamic studies that underpin the clinical use of neuromuscular blocking agents (NMBAs).

Measurement of the force of isometric muscle contraction produced in response to electrical stimulation of a peripheral nerve (mechanomyography, MMG) is considered the gold standard for objective monitoring of neuromuscular transmission (Viby-Mogensen et al. 1996). Unfortunately the equipment for MMG is impractical for routine use in a clinical setting, and no device for clinical use is currently commercially available. Acceleromyography (AMG) is an alternative technique that is used clinically to objectively monitor neuromuscular transmission. It is based on the assumption that the peak acceleration of an extremity in response to nerve stimulation is directly proportional to the force applied to the extremity by muscle contraction (Jensen et al. 1988; Viby-Mogensen et al. 1996). Electromyography (EMG) is another alternative to MMG that has been used to assess neuromuscular transmission in dogs and people under anesthesia (Hanzi et al. 2007; Clark et al. 2012). This technique measures the compound motor action potential produced in muscles after electrical stimulation of a peripheral nerve.

Since AMG measures mechanical activity and EMG is a measure of the sum of cellular activation, there may be systematic differences between the results generated by the two methods. In people, AMG and EMG result in similar measurements for potency of NMBAs, but AMG consistently indicates recovery of neuromuscular transmission before EMG (Kopman et al. 2005a,b; Liang et al. 2013). In other words, AMG overestimates recovery from NMBAs when compared with EMG in people. This observation, however, has not been studied in dogs to our knowledge. This investigation compared the two monitoring techniques during cisatracurium-induced neuromuscular block in dogs under isoflurane anesthesia. The intention was to investigate whether the recovery time would differ between the two monitors, and how the response values (amplitude) for a given parameter of interest would differ between AMG and EMG at a given sampling time point. Specifically, the hypothesis was that AMG and EMG cannot be used interchangeably for monitoring onset and recovery of cisatracurium-induced NMB in dogs.

Methods

This experiment was approved by the Institutional Animal Care and Use Committee. Ten healthy female Beagle dogs, aged 6 months and weighing between 5.0 and 6.6 kg were studied. After overnight fasting, acepromazine (0.02 mg kg^{-1}; Aceproject; Butler Schein Animal Health, OH, USA) was administered intramuscularly (IM) and a catheter was placed in a lateral saphenous vein. Dexmedetomidine (1 μg kg^{-1}; Dexdomitor; Pfizer Animal Health, NY, USA) was administered intravenously (IV), and after about 3 minutes of oxygen supplementation *via* face mask, propofol (30–40 mg; Propoflo; Abbott laboratories, IL, USA) was administered IV and the trachea intubated with a cuffed orotracheal tube. General anesthesia was maintained with isoflurane in oxygen and a dexmedetomidine IV infusion (1 μg kg^{-1} $hour^{-1}$). Lactated Ringer's solution was infused through the IV catheter (5 mL kg^{-1} $hour^{-1}$). The vaporizer setting was adjusted so that no response, other than the expected evoked muscle contractions, was seen during nerve stimulation. This depth of anesthesia was maintained unaltered throughout the time of data collection. Monitoring during general anesthesia consisted of an electrocardiogram (ECG), hemoglobin oxygen saturation (SpO_2) by pulse oximetry, rectal temperature, oscillometric non-invasive arterial blood pressure measurement and end-tidal carbon dioxide tension ($P_E'CO_2$) by capnography. The lungs were mechanically ventilated in order to maintain $P_E'CO_2$ between 35 and 45 mmHg. Dogs were positioned in dorsal recumbency and a forced warm air device was used to maintain esophageal temperature between 36 and 38 °C. A stabilization period of at least 15 minutes without changes in the vaporizer setting was allowed in each dog before data collection commenced.

AMG was monitored with a TOF Watch SX (Organon Ltd, Ireland) and EMG with a M-NMT module of a Datex Ohmeda AS/3 monitor (GE Healthcare, Finland). Each monitor was placed on a thoracic limb; allocation to the left or the right side was assigned randomly by extracting labels from an opaque envelope. Stimulating needles were placed subcutaneously approximately 2.5 cm apart over the ulnar nerves on the medial aspect of the elbows. Train-of-four (TOF) stimulation (pulse duration