Veterinary Anaesthesia and Analgesia, 2008, **35,** 220–227 doi:10.1111/j.1467-2995.2007.00380.x

RESEARCH PAPER

Comparison between acceleromyography and visual assessment of train-of-four for monitoring neuromuscular blockade in horses undergoing surgery

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Abstract

Objective To compare acceleromyography (AMG) with visual assessment of train-of-four (TOF) for monitoring neuromuscular blockade and detecting residual muscle paralysis in horses receiving atracurium.

Study design Prospective, controlled clinical study.

Animals Nine adult, client-owned horses weighing 577 (436, 727) kg (median, minimum, maximum) and ASA physical status I–II, admitted for surgery.

Methods An electrical nerve stimulator was used to stimulate the peroneal nerve with TOFs at 1 minute intervals. Before and after atracurium administration (0.15 mg kg^{-1}, IV), the number of twitches observed (TOF count, or TOFc) was assessed visually. When four twitches were seen (i.e., TOFc = 4) presence or absence of fade by visual assessment was recorded. Simultaneously, the response to each TOF was assessed by AMG; this measured TOFc, and twitch fade using TOF ratio (TOFR; ratio of fourth to first twitch). The anesthetist performing the visual evaluation was blinded to the AMG readings. Recovery from neuromuscular blockade was defined as the absence of fade by visual inspection or a TOFR ≥90% by AMG.

Results During onset of action of the drug, fade was first detected 4 (1, 8) minutes earlier by AMG ($p = 0.008$). Maximal blockade started at 6 (3, 17) minutes by visual assessment and 9 (3, 25) minutes by AMG (not significantly different). Only four horses achieved complete neuromuscular blockade (TOFc of zero by both methods); in those four horses AMG did not detect the start of the return of neuromuscular transmission before visual assessment. Visual assessment indicated the return of four twitches with no fade 12 (8, 42) minutes before AMG gave a TOFR of ≥90% ($p = 0.004$).

Conclusion and clinical relevance There was no substantial advantage for AMG in detecting the onset of atracurium-induced neuromuscular blockade. However, AMG detected residual blockade when visual assessment of TOF did not. Application of AMG is likely to reduce the incidence of residual blockade.

Keywords acceleromyography, atracurium, horse, neuromuscular blockade, residual paralysis.

Introduction

Neuromuscular blocking agents such as atracurium are used as part of anesthetic protocols to provide muscle relaxation for procedures such as fracture

reduction and repair, ophthalmic surgery, thoracotomy, and laparotomy. These agents are also included in most balanced anesthesia protocols.

Monitoring neuromuscular blockade commonly involves electrical stimulation of a peripheral nerve to elicit skeletal muscle contraction and consequent movement. In equine anesthesia, the peroneal and facial nerves have been used for this purpose (Klein 1991; Auer et al. 2003). Although different patterns of electrical nerve stimulation have been described for measuring neuromuscular function, train-of-four (TOF) seems to be the most widely used. Conventionally, this consists of four square-wave stimuli, each 0.2 millisecond duration, given over a period of 2 seconds (i.e., at 2 Hz) (Klein 1991). In the absence of neuromuscular blockade these stimuli induce four similar sized 'twitches' in the muscle distal to the point of stimulation; during complete blockade none of the twitches is seen; during partial blockade the magnitude of the twitches is reduced. Partial blockade produced by nondepolarizing muscle relaxants is characterized by fade (progressive decrease in magnitude over the four twitches). The train-of-four ratio (TOFR) measures fade and is the magnitude of the fourth twitch expressed as a percentage of the magnitude of the first twitch. In human patients TOFR is a sensitive indicator of the amount of neuromuscular transmission (Ali & Savarese 1976; Kopman et al. 2002). A TOFR of 100% represents absence of neuromuscular blockade. Based on clinically relevant tests in humans such as head lifting, forced inspiration, hand griping, and holding an object between the teeth, when TOFR is <90% skeletal motor function is impaired (Eriksson et al. 1997; Kopman et al. 1997, 2002; Sundman et al. 2000; Eikermann et al. 2005; Murphy 2006).

The movement or 'twitches' induced in response to nerve stimulation can be assessed either subjectively or objectively. Subjective monitoring consists of assessing the movement either visually or by palpation and is associated with a high incidence of residual paralysis in people (Ansermino et al. 1996; Murphy et al. 2005). Residual paralysis, occurring during recovery from neuromuscular blockade, is characterized by muscle weakness and is potentially dangerous if undetected (Eriksson et al. 1993, 1997; Eriksson 1999; Eikermann et al. 2005). Residual paralysis has not been investigated systematically in horses. Objective monitoring of neuromuscular transmission involves using a device to measure either the force (mechanomyography), electrical activity (electromyography) or acceleration (acceleromyography, AMG) of the response to nerve stimulation. Although mechanomyography is the gold standard for monitoring neuromuscular function (Viby-Mogensen et al. 1996; Heier & Hetland 1999; Kopman 2002), it is too cumbersome for routine use in a clinical setting. The same disadvantage applies to electromyography for monitoring neuromuscular blockade on patients. Acceleromyography, on the other hand, is easier to apply in the operating room and provides reliable information regarding neuromuscular function in humans (Viby-Mogensen et al. 1988). Acceleromyography produces results similar to electromyography in children (Ansermino et al. 1996), and its use has been recommended for clinical monitoring of neuromuscular transmission during anesthesia in humans (Kopman 2002). The introduction of AMG reduced the incidence of residual neuromuscular blockade from 62% to 3.5% in humans (Baillard et al. 2005). Acceleromyography has been used to show that superficial peroneal and auriculopalpebral nerve stimulation have equivalent sensitivity for measuring neuromuscular transmission in horses (Auer et al. 2003).

Subjective visual monitoring of TOF stimulation is still widely used in equine practice and at the time of this study was the only method used in our clinic. However, extrapolating from work largely carried out in humans, we hypothesized that neuromuscular transmission may still be impaired when visual assessment of TOF indicates complete recovery from atracurium-induced neuromuscular blockade in horses.

Materials and methods

Animals

Nine horses admitted to the Cornell University Hospital for Animals were included in the study (Table 1). They were scheduled for surgical procedures that required general anesthesia for more than 1 hour and for anesthetic protocols that ordinarily included neuromuscular blockade. The single deviation from normal practice was the measurement of hoof acceleration (see below). All patients were classified as ASA physical status I or II based on preanesthetic physical examination and measurement of packed cell volume and total solid concentration in plasma. None of the patients showed signs of neuromuscular disease. The anesthetic protocol was