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ORIGINAL ARTICLE

Monitoring masseter muscle evoked responses enables faster tracheal intubation

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Abstract

Purpose The aim of this study was to investigate whether monitoring neuromuscular block at the masseter muscle (MM) would allow faster tracheal intubation when compared with that at the adductor pollicis muscle (APM).

Methods Twenty female patients undergoing gynecological surgery were enrolled into this study. Immediately after inducing anesthesia with fentanyl and propofol, both the left masseter and ulnar nerves were stimulated in a 2 Hz train-of-four (TOF) mode using peripheral nerve stimulators. Contractions of the MM were felt with the anesthesiologist's left hand lifting the patient's jaw and holding an anesthesia facemask, while those of the APM were visually observed. Immediately after the contracting responses of the muscles were confirmed, all of the patients received an iv bolus of vecuronium 0.1 mg kg^{-1}. Onset times after vecuronium were defined as the duration until the contractions became impalpable at the MM or invisible at the APM. When the contraction of the MM could no longer be felt, the conditions for laryngoscopy and tracheal intubation were assessed.

Results Onset time evaluated tactually at the MM (mean $\pm$ SD, 108.4 $\pm$ 27.7 s) was significantly shorter than that evaluated visually at the APM (181.2 $\pm$ 32.1 s, $P < 0.0001$). The intubating conditions for all patients were graded as either excellent or good.

Conclusion Tactual evaluation of muscle paralysis of the MM during induction of anesthesia is clinically useful since it leads to faster tracheal intubation.

Keywords Neuromuscular block · Masseter muscle · Adductor pollicis muscle · Vecuronium

Introduction

When inducing general anesthesia, the patient's lungs are manually ventilated using an anesthesia facemask and bag until the effect of the neuromuscular blocking drug is established. In patients with difficult airways or full stomachs, performing tracheal intubation as quickly as possible improves patient safety. Therefore, neuromuscular monitoring is highly beneficial to achieving the fastest and safest tracheal intubation. Clinically, the time course of neuromuscular block is often evaluated at the adductor pollicis muscle (APM). However, neuromuscular block at the APM does not occur fast enough when rapid tracheal intubation is needed, because the onset of paralysis of the APM is slower than that of the laryngeal muscles [1] and diaphragm [2, 3]. Direct measurements of neuromuscular block in the respiratory muscles are not easy and suitable to perform while inducing anesthesia. In contrast, neuromuscular blocking effects appear at the masseter muscle (MM) more rapidly than at the APM [4–6], and result in jaw relaxation during laryngoscopy. It was anticipated that the speed of onset of neuromuscular block at the MM might be similar to those at the laryngeal muscles and diaphragm, and that monitoring the MM could lead to more rapid and safer tracheal intubation. Several previous studies

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[4–6] have already shown using acceleromyography or mechanomyography that onset occurs more rapidly at the MM when compared with the APM. However, it is difficult to apply transducers to monitor muscle contractions objectively in clinical practice because movement of the patient's jaw is restricted by the anesthesiologist's hand while inducing general anesthesia. The aim of this study was to examine whether tactile evaluation of contractions of the MM could be used to monitor neuromuscular block for faster tracheal intubation.

Methods

After the protocol had been approved by the Hospital Ethics Committee on Human Rights in Research, 20 adult female patients consented to participate in this study. The patients were ASA physical status I or II, 23–47 years of age, and were undergoing elective gynecological surgery. None of the patients had neuromuscular, hepatic or renal disorders, or were taking any drug known to interact with neuromuscular blocking agents. Patients with BMIs that were $\geq$25 or <18.5 were also excluded from the study. Premedication consisted of orally administered ranitidine 150 mg before going to bed on the day before surgery and on the morning of the day of surgery, and diazepam 5 mg 1 h before entering the operating room. On arrival at the operating room, all patients were monitored for ECG, noninvasive blood pressure and pulse oximetry. Stimulation electrodes were attached percutaneously to the left ulnar nerve at the wrist and the left masseter nerve at the space formed by the zygomatic arch superiorly and the mandibular notch inferiorly (Fig. 1), and two peripheral nerve stimulators (Innervator NS-252, Fisher & Paykel Electronics, Auckland, New Zealand) were used to separately stimulate the ulnar and masseter nerves. General anesthesia was induced with fentanyl 2–4 μg kg^{-1} and propofol 1–2 mg kg^{-1} while the patients received 100% oxygen through an anesthesia facemask. After loss of consciousness, the nerves were concurrently stimulated with square-wave stimuli of 0.2 ms duration delivered in a train-of-four (TOF) mode at 2 Hz every 12 s. An output current of 50 mA was applied to the ulnar nerve, while 20–30 mA were used to stimulate the masseter nerve in order to avoid stimulating other facial muscles [7] and directly stimulating the MM. Contractions of the MM were palpated with the anesthesiologist's left palm while lifting the patient's jaw and holding the anesthesia facemask (Fig. 2). If contractions of the MM could not be sufficiently sensed, the stimulating current was gradually increased from 20 mA to allow muscle contractions to be palpated. Contractions of the APM were also observed visually by another evaluator. The patients then received an iv bolus dose of vecuronium 0.1 mg kg^{-1}. The onset time at the MM was defined as the duration until the contracting response of the MM became impalpable, and that at the APM was defined as the duration until adduction of the thumb could not be observed visually. Immediately after onset at the MM had been confirmed, the patient's trachea was intubated with a 7.0 mm ID endotracheal tube (Portex Tracheal Tube, Smiths Medical International Ltd., Kent, UK), and the intubating conditions (Table 1) [8] were assessed.

The sample size was calculated based on preliminary data on an averaged onset time of vecuronium 0.1 mg kg^{-1} observed at the APM (172 $\pm$ 42 s). We considered a 30% decrease in the onset time at the MM to be clinically relevant. To obtain statistically significant results with

Fig. 1 Positions of the electrodes used to stimulate the masseter nerve

Fig. 2 Contractions of the masseter muscle were palpated with the anesthesiologist's left palm while lifting the patient's jaw and holding the anesthesia facemask

Table 1 Evaluation of the intubating conditions [8]

Variable assessed	Excellent	Good	Poor
Laryngoscopy	Easy	Fair	Difficult
Position of vocal cords	Abducted	Intermediate/moving	Closed
Diaphragmatic movement or cough after tracheal intubation	None	Slight	Vigorous/sustained

Excellent, all qualities are excellent; good, all qualities are either excellent or good; poor, the presence of a single quality listed under poor

$\alpha = 0.05$ and a power of 0.9, we needed 15 patients to be included in this study. Because some patients withdrew from the study, we finally enrolled 20 patients. Data are presented as mean ± SD. Statistical analysis was performed using StatView software for Windows (SAS Institute, Cary, NC, USA). The unpaired Student's t test was used for group comparisons. A P value of <0.05 was considered statistically significant.

Results

The average age, weight and height of the patients were 39.4 ± 5.4 years, 55.4 ± 8.1 kg and 159.0 ± 4.6 cm, respectively. The onset time was significantly faster at the MM (108.4 ± 27.7 s, $P < 0.0001$) than the APM (181.2 ± 32.1 s). The intubating conditions were graded as excellent in 12 patients and good in 8 patients. None of the patients had poor intubating conditions.

Discussion

This study demonstrated that muscle paralysis of the MM induced by vecuronium was significantly faster than that of the APM and could certify clinically acceptable conditions for laryngoscopy and tracheal intubation. Subjectively sensing the disappearance of contractions of the MM may enable faster tracheal intubation in patients at risk of pulmonary aspiration or who may have a difficult airway.

Previous studies [4–6] have revealed using acceleromyography or mechanomyography that onset of neuromuscular blocking occurs significantly faster at the MM than at the APM. Unfortunately, the monitoring was performed in such studies during a steady state of anesthesia after laryngeal mask insertion [4] or tracheal intubation [5, 6]. The important characteristic of rapid onset of paralysis at the MM should be utilized during induction of general anesthesia, but MM monitoring has previously proven difficult because an acceleration or force transducer cannot correctly assess jaw movement during mask-to-face ventilation. Consequently, in order to perform MM monitoring in the clinical setting, we palpated contractions of the MM evoked by a simple peripheral nerve stimulator during mask ventilation, and subjectively assessed the onset of paralysis based on the disappearance of contractions. This procedure was proven to be of clinical use for determining the earliest suitable time at which laryngoscopy and tracheal intubation could be performed.

Jaw relaxation, opening of the glottis and prevention of cough reflex are required to perform laryngoscopy and tracheal intubation easily and safely [8]. To satisfy these conditions, the MM, the laryngeal muscle and the diaphragm must be sufficiently relaxed. The clinically acceptable intubating conditions demonstrated at the MM in this study suggest that the onset of neuromuscular block at the MM occurs as rapidly as that at the laryngeal muscle and diaphragm. The degree of neuromuscular blocking varies at different muscles. The onset of neuromuscular block at the laryngeal muscle [1] and diaphragm [2, 3] has been shown to be faster than that at the APM. These findings may be due to the large volume of blood flowing to the centrally located muscles [3] and the faster transfer rate of neuromuscular blocking drugs between plasma and the laryngeal neuromuscular junction [9]. The volume of blood flow in the MM is large, as it is for the respiratory muscles. Previous studies have demonstrated that the muscle blood flow in the MM (12.3 mL 100 g^{-1} min^{-1}) [10] is more than 4 times higher than that in the APM (2.9 mL 100 g^{-1} min^{-1}) [11]. This discrepancy may be related to the difference in the onset times for the action of vecuronium between the two muscles in this study. Furthermore, sensitivity to neuromuscular blocking agents alters according to muscle fiber composition [12]. That is to say, the number of postsynaptic nicotinic acetylcholine receptors per unit muscle surface area is smaller in type I fiber-dominant muscles [13]. The MM contains a high percentage of type I fibers [14]. It is therefore conceivable that the faster onset of the action of vecuronium at the MM may result from a high susceptibility to nondepolarizing muscle relaxant and a larger muscle blood flow.

In this study, smaller currents were used to stimulate the masseter nerve compared with the ulnar nerve. It is well known that the strength of electrical nerve stimulation is very important in pharmacodynamic studies of neuromuscular blocking agents [15]. Therefore, it is possible that the masseter nerve stimulation does not reach the supramaximal level and the different stimulating currents cause a significant difference in the onset of vecuronium-induced neuromuscular block between the MM and APM. However, in order to accurately evaluate muscle paralysis of the MM, stimulation of other facial muscles and direct muscle stimulation of the MM must be avoided. In facial nerve stimulation, small currents (20–30 mA) are recommended in order to accurately monitor contracting responses of the corrugator supercilii muscle [7]. Because the electrodes are positioned close to the MM, small currents seem to be appropriate for stimulating the masseter nerve. Similarly, it is reasonable to consider that a stimulating current of 50 mA for the ulnar nerves is not supramaximal. Movement of the thumb was not monitored objectively in this study, so the supramaximal current could not be calculated. If a larger current is used to stimulate the ulnar nerve, a further difference in onset may be detected between the MM and APM.

Contractions of the MM were only sensed by the anesthesiologist's hand, so it is undeniable that the results of this study may depend to some extent on the bias of the evaluator. However, it is not very difficult to tactually perceive the MM contracting or paralyzing during the induction of general anesthesia. As can be seen from the excellent or good intubation conditions obtained, the assessment method used in this study is considered appropriate for predicting the timing of tracheal intubation.

In conclusion, tactile assessment of muscle paralysis of the MM after administration of vecuronium enables faster tracheal intubation and may improve patient safety.

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