British Journal of Anaesthesia **110** (4): 567–76 (2013)
Advance Access publication 1 February 2013 · doi:10.1093/bja/aes395

BJA

NEUROSCIENCES AND NEUROANAESTHESIA

Comparison of motor-evoked potentials monitoring in response to transcranial electrical stimulation in subjects undergoing neurosurgery with partial *vs* no neuromuscular block†

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Editor's key points

- Motor-evoked potential monitoring is commonly performed during neurosurgery to monitor the integrity of the motor pathways.
- Maintenance of neuromuscular block after tracheal intubation can interfere with MEP monitoring.
- Some anaesthetists nonetheless maintain partial neuromuscular block during MEP monitoring to prevent evoked and spontaneous movements.
- The authors compared MEP amplitudes and variability during different degrees of partial neuromuscular block.

Background. There have been no evidence-based comparisons of motor-evoked potential (MEP) monitoring with no and partial neuromuscular block (NMB). We compared the effects of different levels of NMB including no NMB on MEP parameters.

Methods. MEP-monitored 120 patients undergoing neurosurgery were enrolled. The patients were randomly allocated to four groups: Group A was to maintain two train-of-four (TOF) counts; Group B was to maintain a T_1/Tc of 0.5; Group C was to maintain a T_2/Tc of 0.5 ($T_{1,2}$, first or second twitch height of TOF; Tc, control twitch height); Group D did not maintain NMB. The mean MEP amplitude, coefficient of variation (CV), the incidence of spontaneous respiration or movement, the efficacy of MEP, and haemodynamic parameters were compared.

Results. The median [inter-quartile range (IQR)] amplitudes of the left leg for Groups A, B, C, and D were 0.23 (0.15–0.57), 0.44 (0.19–0.79), 0.28 (0.15–0.75), and 0.75 (0.39–1.35) mV, respectively. The median (IQR) CVs of the left leg were 71.1 (56.9–88.8), 76.1 (54.2–93.1), 59.8 (48.6–95.6), and 25.2 (17.3–35.0), respectively. The differences between groups of the mean amplitudes of the left arm and both legs were statistically significant (Kruskal–Wallis test, $P=0.011$ for the left leg). For all limbs, the differences between groups of the CVs were significant ($P<0.001$, for the left leg). Other parameters were not different.

Conclusions. If NMB is used during MEP monitoring, a target T_2/Tc of 0.5 is recommended. In terms of the MEP amplitude and variability, no NMB was more desirable than any level of partial NMB.

Keywords: motor-evoked potentials; neuromuscular block; neurosurgery; vecuronium

Accepted for publication: 31 August 2012

While muscle relaxation is not desirable for intraoperative motor-evoked potential (MEP) monitoring during neurosurgery, some surgeons, neurophysiologists, and anaesthesiologists still prefer to use the continuous infusion of neuromuscular blocking agents to maintain partial neuromuscular block (NMB).[1–7] Those who advocate for partial NMB insist that the complete omission of NMB could result in problems such as difficulty in exposing the surgical field, especially during spine surgery, and also the risk of unexpected patient movement.[2 5 6] However, most institutions do not use neuromuscular blocking agents during MEP[8–11] as NMB can reduce the MEP amplitude.[12 13]

Authors who have advocated partial NMB recommend a blockade with T_1 between 5% and 50% of baseline or one or two twitches in a train-of-four (TOF) electrical stimulation of the ulnar nerve.[5–7 14–17] However, in our experience, these levels of NMB seem to cause significant depression and fluctuation in the MEP amplitude and some controversy exists regarding the allowable degree of muscle relaxation for MEP monitoring.[6] There have been no evidence-based comparisons of partial NMB and no NMB on MEP monitoring amplitude, variability, or efficacy. Additional data on anaesthetic parameters such as spontaneous patient movement and haemodynamics are similarly unavailable. As such, there is

† This article is accompanied by Editorial III.

a need to determine the allowable degree of partial NMB during MEP and to compare these effects with those observed when not maintaining NMB.

Towards this purpose, we evaluated the effects of various levels of controlled muscle relaxation, including no NMB, on MEP parameters, efficacy, and other anaesthetic parameters.

Methods

Patients

This study was approved by the Samsung Medical Centre Institutional Review Board (2011-04-010) and registered at www.clinicaltrials.gov (protocol ID NCT01388868). All patients provided informed consent. Between June 2011 and February 2012, patients were enrolled in this prospective randomized study if they were receiving MEP monitoring while undergoing cerebral aneurysm clipping or if they were having tumours removed through craniotomies or spinal laminectomies. Patients were excluded from the study if they had an ASA physical status classification of III or greater. Those who could not undergo MEP monitoring due to central or peripheral neuromuscular diseases such as cerebral palsy, myasthenia gravis, acute spinal injury, or neurologic shock were also excluded from the present study.

General anaesthesia and study protocol

Anaesthesia was induced by i.v. propofol (4–6 μg ml^{-1}) with remifentanil (2–4 ng ml^{-1}) through a target-controlled infusion pump (Orchestra^{TM}, Fresenius Vial, France). After induction, tracheal intubation was facilitated with rocuronium (0.6 mg kg^{-1}). Before rocuronium administration, the baseline twitch response was established with a neuromuscular transmission module (M-NMT Module®, Datex-Ohmeda Inc., Helsinki, Finland). This module automatically searched for the stimulus current to achieve the maximum response of the adductor pollicis muscle. The maximum electromyographic amplitude of T_1 before rocuronium administration was considered to be the control response (Tc). Anaesthesia was maintained with propofol and remifentanil infusions through the Orchestra pump. Remifentanil was titrated at a dose range of 2–5 ng ml^{-1} to control the haemodynamic response to the surgical procedure within a 20% range of its preoperative value, and propofol was infused at a dose range of 3–6 μg ml^{-1}. The remifentanil dose was adjusted by 1 ng ml^{-1} until the mean arterial pressure was maintained within the target range and did not decrease below 2 ng ml^{-1}. The mean arterial pressure during the surgery was recorded every 5 min and was compared between the groups. Hypotension was defined as a decrease in the mean arterial pressure of more than 20% of the preoperative value or below 55 mm Hg and was treated by repeated 5 mg i.v. ephedrine bolus doses. Vasopressor infusion (phenylephrine 0.3–1.0 μg kg^{-1} min^{-1}) was given if three or more ephedrine bolus doses were required. If bradycardia ($<$60 beats min^{-1}) developed, 0.5 mg of atropine was administered. All patients were administered 4 ml kg^{-1} h^{-1} of lactated Ringer's solution during surgery, and blood loss was replaced by Voluven® (Fresenius Kabi, Bad Homburg, Germany). The use of these drugs was compared between the groups. Continuous end-tidal CO_2 monitoring was performed and maintained within a range of 4.0–4.7 kPa. Intraoperative monitoring included continuous ECG, pulse oximetry, arterial pressure (via arterial line and non-invasive arterial pressure cuff), and oesophageal temperature. The monitoring of transcranial electrophysiology for major brain or spinal cord surgery was performed by recording MEP and somatosensory-evoked potentials. The muscle being recorded for TOF and MEP was kept warm to maintain body temperature with a warm blanket.

Subjects were randomly allocated into one of the four groups and were given doses of the neuromuscular blocking agent vecuronium adjusted every 15 min according to the group's NMB target. For the groups receiving partial NMB, the goals were as follows: Group A was to maintain a two-count response of TOF stimulation of the ulnar nerve; Group B was to maintain a 0.5 twitch height of the first evoked response of TOF stimulation (T_1) compared with the control twitch (Tc); Group C was to maintain a 0.5 twitch height of the second evoked response of TOF stimulation (T_2) compared with Tc. Group D did not receive vecuronium infusion.

The primary outcome measurement of the present study was the MEP amplitude, and also the coefficient of variation (CV, %) of all measured MEP amplitudes. This CV was calculated as the standard deviation (SD) of the MEP amplitude divided by the mean value. The MEP amplitude was obtained and recorded by the neurophysiologists (i) at baseline after the rocuronium was administered (TOF count of 4 and T_1/Tc of about 75%) and before the vecuronium infusion was started and (ii) at 15 min intervals throughout the period of MEP monitoring (Fig. 1).

Other variables measured and compared among the groups during surgery were (i) the incidence of patient spontaneous movements or respiration during MEP monitoring, (ii) any positive MEP changes during the surgery, (iii) the new onset of postoperative neurological dysfunction, (iv) the doses of anaesthetics administered, and (v) the continuous end-tidal CO_2 measurements. Spontaneous movement was reported by the attending surgeon, who was blinded to the study group of the patient. The anaesthesiologist then measured and recorded whether the movement occurred during microscopic (e.g. removal of tumour or clipping of aneurysm) or macroscopic (e.g. dissection of the surgical field) surgery. Spontaneous respiration was reported by the attending anaesthetists.

The response of the adductor pollicis brevis muscle to TOF stimulation of the ulnar nerve by the NMT module was monitored every 15 min, and the infusion dose of vecuronium was adjusted according to the target of the partial NMB group. In Group D, no neuromuscular blocking agent was infused after the intubating dose of rocuronium. After the surgery, the neurosurgeon evaluated the presence of neurological dysfunction, and neurophysiologists evaluated its correlation with intraoperative positive changes in MEP. Reductions in the MEP amplitude of $>$50% or a loss of MEP for three consecutive