R. Martin MD, I. Bourdua MD, S. Thériault MD,
J.P. Tétrault MD, M. Pilote RN

Neuromuscular monitoring: does it make a difference?

Purpose: The objective of the present prospective study was to evaluate the influence of neuromuscular monitoring on the level of neuromuscular blockade from induction of anaesthesia until extubation of the trachea.

Methods: Forty-two patients aged between 18 and 73 yr undergoing a range of surgical procedures under general anaesthesia were randomly distributed into two groups of 21 patients each. In both groups a Datex NMT Monitor® was used and electromyographic responses of the the ulnar muscles to supramaximal stimulation of the ulnar nerve were recorded. In Group 1, the anaesthetist could see the movements of the stimulated hand, but not the monitor. In Group 2, the anaesthetist could see neither the stimulated hand nor the monitor. The same anaesthetist administered the neuromuscular relaxants which were succinylcholine $1.5 \text{ mg} \cdot \text{kg}^{-1}$ for tracheal intubation and vecuronium $0.1 \text{ mg} \cdot \text{kg}^{-1}$ for neuromuscular relaxation during surgery, followed by 1 to 2 mg maintenance injections. Possible residual curarization was evaluated in the recovery room by head lift tests and pulse oximetry.

Results: Patients in Group 1 had deeper neuromuscular block throughout surgery, despite the use of a comparable dose of vecuronium (10.1 mg for G1 vs 11.2 mg for G2). The EMG values of T_1 and train-of-four values were not different at tracheal intubation or at extubation. No patients presented signs of residual curarization in the recovery room.

Conclusion: The study demonstrates that with the same amount of vecuronium the neuromuscular relaxation was deeper with the use of a simple neuromuscular monitoring (visual evaluation of the thumb movements). Despite the deeper neuromuscular block in the monitored group, there was no residual curarization in the recovery room.

Key words

MONITORING: neuromuscular function;
NEUROMUSCULAR RELAXANTS: succinylcholine,
vecuronium.

From the Department of Anaesthesia, University of Sherbrooke, P. Quebec, Canada.

Address correspondence to: Dr. R. Martin, Department of Anaesthesia, CUSE, 3001, 12th Avenue North, Fleurimont, PQ, J1H 5N4.

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Objectif: Le but de la présente étude était d'évaluer l'influence de l'utilisation d'un monitoring de curarisation sur le niveau de curarisation et ce, de l'induction de l'anesthésie jusqu'à l'extubation de la trachée.

Méthode: Quarante-deux patients âgés de 18 à 73 ans prévus pour différentes chirurgies sous anesthésie générale ont été répartis au hasard en deux groupes de 21 patients. Dans les deux groupes un moniteur Datex NMT® a été utilisé et les réponses électromyographiques des muscles de l'éminence thénar suite à une stimulation supramaximale de nerf cubital ont été enregistrées. Dans le groupe 1, l'anesthésiste pouvait voir la main stimulée mais non le moniteur. Dans le groupe 2, l'anesthésiste ne pouvait voir ni la main ni le moniteur. Le même anesthésiste a donné les curares qui étaient de la succinylcholine à $1.5 \text{ mg} \cdot \text{kg}^{-1}$ pour l'intubation endotrachéale et du vécuronium à $0.1 \text{ mg} \cdot \text{kg}^{-1}$ pour la relaxation neuromusculaire pendant la chirurgie, dose qui était suivie de réinjections de maintien de 1 à 2 mg. Une curarisation résiduelle possible a été évaluée en salle de réveil par les valeurs de saturation et des tests de soutien de la tête.

Résultats: Les patients du groupe 1 ont montré des niveaux de curarisation plus profonds tout au long de la chirurgie, et ceci malgré l'utilisation de doses comparables de vécuronium (10.1 mg pour le G1 et 11.2 mg pour le G2). Les valeurs du T_1 de l'EMG et du train-de-quatre n'étaient pas différentes lors de l'intubation endotrachéale et de l'extubation. Aucun patient n'a présenté de signes de curarisation résiduelle en salle de réveil.

Conclusion: Cette étude montre qu'avec une même quantité de vécuronium la relaxation neuromusculaire est plus importante lorsqu'il y a utilisation d'un monitoring neuromusculaire simple (évaluation visuelle des mouvements du pouce). Également, en dépit d'un bloc neuromusculaire plus profond dans le groupe avec moniteur, il n'y a pas eu de curarisation résiduelle dans ce groupe en salle de réveil.

Clinical neuromuscular monitoring is frequently but not always used.^{1,2} A local survey of 51 staff anaesthetists revealed that 16% of anaesthetists used neuromuscular monitoring in <50% of cases. Moreover, a recent study of residual curarisation after administration of atracurium or vecuronium by bolus doses or infusions revealed that a peripheral nerve stimulator (PNS) was not used in

45% of the cases.² As stated by Viby-Mogensen: "Many anesthesiologists do not agree with the extensive use of nerve stimulators and argue that they manage quite well without these devices".¹

The objectives of the present study were to evaluate the influence of a neuromuscular blockade monitor on the level of neuromuscular blockade induced by succinylcholine and vecuronium from the time of induction of anaesthesia until the time of extubation of the trachea.

Methods

After institutional approval and informed consent 42 patients aged 8–73 yr and free of neuromuscular disorders were randomly distributed into two groups of 21 according to a random number table. They were scheduled for a range of surgical procedures under general anaesthesia including neurosurgery, orthopedic surgery, ophthalmic surgery and gastro-intestinal surgery. In Group 1, the anaesthetist (the same for all the patients) could see the stimulated hand but could not see the monitor. In Group 2, the anaesthetist could see neither the hand nor the monitor. The objectives of the anaesthetist for both groups were: (a) to achieve tracheal intubation after effect of succinylcholine $1.5 \text{ mg} \cdot \text{kg}^{-1}$ which was preceded two minutes earlier by vecuronium $0.01 \text{ mg} \cdot \text{kg}^{-1}$ and an induction dose of thiopentone $5\text{--}7 \text{ mg} \cdot \text{kg}^{-1}$ or propofol $2\text{--}2.5 \text{ mg} \cdot \text{kg}^{-1}$; (b) to administer vecuronium $0.1 \text{ mg} \cdot \text{kg}^{-1}$ after partial recovery from succinylcholine; (c) to maintain surgical relaxation throughout surgery which would be adequate for an abdominal surgery using maintenance injections of vecuronium 1 or 2 mg; (d) to antagonize the neuromuscular block with neostigmine $0.04 \text{ mg} \cdot \text{kg}^{-1}$ and glycopyrrolate $0.01 \text{ mg} \cdot \text{kg}^{-1}$ and to extubate the trachea when the patient had fully recovered from neuromuscular relaxant and was awake. In Group 1, the trachea was intubated after disappearance of the thumb responses, the first dose of vecuronium was given after the reappearance of one twitch, the presence of only the first or the first and the second thumb movement was maintained throughout the surgery, the neuromuscular antagonists was given when at least the first movement was present, and complete recovery from the neuromuscular relaxant was evaluated by the presence of the four thumb movements, without apparent fade. In Group 2, the anaesthetist intubated the trachea when, according to clinical criteria, succinylcholine had fully relaxed the patient. Vecuronium was given when the patient had recovered from succinylcholine. The maintenance injections of vecuronium were subsequently arbitrarily administered to maintain relaxation adequate for abdominal surgery. The reversal of vecuronium was

always given 30 to 40 min after the last dose of vecuronium in group 2 and the trachea was extubated when the anaesthetist estimated that the patient had fully recovered from his muscular relaxation. Finally, in both groups, the presence of diaphragmatic movement at the time of tracheal intubation was noted as were the lowest oxygen blood saturation in the recovery room, and the ability of the patient to sustain a head lift for 5 sec on arrival in the recovery room. The neuromuscular monitoring used was a Datex NMT Monitor® (Puritan-Bennett). This is an evoked electromyography (EMG) monitor which utilizes the integration of the EMG response (area under the curve). Surface electrodes were used. The muscle responses of the thenar eminence were studied following stimulation of the ulnar nerve at the wrist with a supramaximal current determined for each patient before the administration of succinylcholine ($56 \text{ MA} \pm 7$). Train-of-four ratios, EMG values of T_1 , compared with control, were observed in both groups: (1) at the time of tracheal intubation; (2) at the time of the initial and subsequent injections of vecuronium; (3) at the time of neostigmine/glycopyrrolate injections; (4) at the time of estimated complete recovery from neuromuscular relaxants. Other monitors included: ECG, non-invasive oscillometry blood pressure pulse oximetry, capnography, anaesthetic gas concentrations and oesophageal temperature.

After an initial bolus of sufentanil $0.3\text{--}0.5 \text{ } \mu\text{g} \cdot \text{kg}^{-1}$ or alfentanil $20\text{--}30 \text{ } \mu\text{g} \cdot \text{kg}^{-1}$ which preceded thiopentone $5\text{--}7 \text{ mg} \cdot \text{kg}^{-1}$ or propofol $2\text{--}2.5 \text{ mg} \cdot \text{kg}^{-1}$, anaesthesia was maintained with sufentanil $10\text{--}20 \text{ } \mu\text{g}$ or alfentanil $500 \text{ } \mu\text{g}$ bolus injections. The patients breathed $\text{N}_2\text{O}/\text{O}_2$ (60%/40%) with isoflurane (0.5 to 1% inspired) throughout surgery and some outpatients received a propofol infusion of 100 to $200 \text{ } \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. The lungs were mechanically ventilated to maintain PaCO_2 between 30 to 40 mmHg.

Unpaired *t* tests were used for comparisons between the two groups for parametric values and chi-squared tests for non-parametric values. A *P* value <0.05 was considered statistically significant.

Results

There were no differences in the age, sex, height, duration of surgery, duration of anaesthesia or total dose of vecuronium between groups. However, patients in Group 1 weighed more than patients in Group 2 (75.4 kg vs 66.9 kg), (Table I).

The EMG values of T_1 and the incidence of diaphragmatic movement at the time of tracheal intubation did not differ between the two groups (Table II).

The time from succinylcholine injection and the initial injection of vecuronium ($0.1 \text{ mg} \cdot \text{kg}^{-1}$) was less in

TABLE I Demographic data

	Group 1 (neuromuscular monitoring)	Group 2 (no neuromuscular monitoring)	Statistical probability
Age (years)	46.6 ± 14.6	42.2 ± 16.5	N.S.
Sex (F / M)	8 / 13	10 / 11	N.S.
Weight (kg)	75.4 ± 14.8	66.9 ± 11.8	<i>P</i> = 0.047
Height (cm)	166.6 ± 11.6	165.3 ± 10.4	N.S.
Duration of surgery (min)	91.9 ± 53.2	122.4 ± 69.1	N.S.
Total dose of ve- curonium (mg)	10.12 ± 4.2	11.25 ± 4.2	N.S.

(Mean ± SD).

TABLE II EMG values of T_1 and diaphragmatic movements at the time of endotracheal intubation

	EMG val- ues of T_1 * (% ± SEM)	Diaphragmatic movements* (% of patients)
Group 1 (neuromuscular monitoring)	1.5 ± 0.6	38
Group 2 (no neuromuscular monitoring)	6.2 ± 2.5	48

**P* = N.S.TABLE III Time from succinylcholine administration and first injection of vecuronium and EMG values of T_1

	Time * min (± SEM)	EMG values of T_1 (% ± SEM)
Group 1 (neuromuscular monitoring)	7.5 ± 1.2	18.1 ± 3.9
Group 2 (no neuromuscular monitoring)	5.0 ± 0.2	12.5 ± 4.1

**P* < 0.05

the no neuromuscular monitoring group (gr 2), but the EMG values of T_1 were not different (Table III).

The train-of-four values at the times of vecuronium bolus injections during surgery, before antagonism of neuromuscular blockade and at the time of extubation of the trachea are shown in Figure 1. Neuromuscular block was more profound throughout the surgery in the monitored group (gr 1) than in the non-monitored group (gr 2) *P* < 0.05, except at the time of reversal of neuromuscular blockade and extubation of the trachea. In the no neuromuscular monitoring group the time from the initial and first maintenance dose of vecuronium was less than in the monitored group but the times between the second and third and between the third and fourth injection were longer in the non-monitored group (*P* < 0.05) (Figure 2).

FIGURE 1 Train-of-four ratios expressed in percentage at the times of different anaesthetic events: 1–7 = Vecuronium 1–2 mg bolus injections during surgery; 8 = Neuromuscular blockade reversal; 9 = Extubation of the trachea criteria satisfied. **P* < 0.05 (no monitoring vs monitoring).

FIGURE 2 Times between first and second, second and third and third and fourth vecuronium injections. **P* < 0.05.

Discussion

In the present study, according to integrated EMG values, patients where the physician anaesthetist could see the hand stimulated every 20 sec in a train-of-four mode

had lower train-of-four ratios throughout surgery than did patients with no monitoring (Figure 1). The study also demonstrated that, without monitoring, neuromuscular relaxants are administered at more regular intervals than in the monitored group (Figure 2).

To our knowledge, this is the first time that a study compared the degree of muscular relaxation between one group of patients managed solely by clinical criteria and another group managed with the aid of a neuromuscular monitor. The use of such a monitor was suggested for all patients more than 10 yr ago³ but, as we can observe in our survey and in a recent study,² it is not used for all patients. This monitor is not considered mandatory but "should be immediately available" according to guidelines of practice of anaesthesia in Quebec and in Canada.^{4,5}

What are the optimal levels of blockade? In the present study we had gastro-intestinal (G-i) surgery and we tried to produce a neuromuscular block that would be adequate for such a surgery in all patients. According to the train-of-four values showed in Figure 1, the monitored group had a neuromuscular block level adequate for G-i surgery, but this was not the case in the non-monitored group where the four responses to train-of-four stimulation were always present.

The problems with the present study could be related to the small number of patients studied ($n = 42$) and to the fact that a single observer assessed all the cases. The small number of patients is not a problem when we find statistically significant results as in the present study. Also, a single observer might be considered to be an advantage, because the same evaluation criteria were used rigorously for all the patients.

The clinical relevance of the study is that the same amount of vecuronium was used in the two groups of patients with different results. It shows that a more profound block can be obtained with good timing of neuromuscular relaxant administration.

The results of the present study apply only to vecuronium which is a neuromuscular relaxant of intermediate duration. It is not surprising that no case of residual curarization as evaluated by a very sensitive test (head lifts tests) was observed with this drug.⁶ When possible, this test is less misleading than tactile and visual evaluation of double burst and train-of-four response,⁷⁻⁸ the latter being better than no monitoring at all during the surgery.⁹

In conclusion, a deep neuromuscular block was obtained in the group of patient monitored with a simple neuromuscular block monitoring. Such a deep block was not achieved in a group of patient without neuromuscular monitoring. No signs of residual curarization were observed in the recovery room in any patient.

References

- 1 *Viby-Mogensen J.* Neuromuscular monitoring. In: Miller RD (Ed.). *Anesthesia*, 4th ed. New York: Churchill Livingstone Inc., 1994: 1359.
- 2 *Fawcett WJ, Dash A, Francis GA, Liban JB, Cashman JN.* Recovery from neuromuscular blockade: residual curarization following atracurium or vecuronium by bolus dosing or infusions. *Acta Anaesthesiol Scand* 1995; 39: 288-93.
- 3 *Viby-Mogensen J.* Clinical assessment of neuromuscular transmission. *Br J Anaesth* 1982; 54: 209-23.
- 4 *Guide de l'exercice de l'anesthésie.* Publication de la corporation professionnelle des médecins du Québec, 1992; 6.
- 5 *Directives relatives à l'exercice de l'anesthésie tel que recommandé par la Société canadienne des anesthésistes.* Publication de la Société canadienne des anesthésistes, 1987; 9.
- 6 *Bevan DR, Smith CE, Donati F.* Postoperative neuromuscular blockade: a comparison between atracurium, vecuronium, and pancuronium. *Anesthesiology* 1988; 69: 272-6.
- 7 *Viby-Mogensen J, Jensen NH, Engbaek J, Ørding H, Skovgaard LT, Chraemmer-Jorgensen B.* Tactile and visual evaluation of the response to train-of-four stimulation. *Anesthesiology* 1985; 63: 440-3.
- 8 *Kilis J, Martineau R, Miller D, Hull K, Lindsay P, Curran M.* Evaluation of the peripheral nerve stimulator vs EMG for monitoring neuromuscular block during continuous infusion of atracurium. *Can J Anaesth* 1993; 40: A56.
- 9 *Shorten GD, Merk H, Sieber T.* Perioperative train-of-four monitoring and residual curarization. *Can J Anaesth* 1995; 42: 711-5.