Surgeon-controlled mivacurium administration during elective Caesarean section

Mohamed Abdulatif MB BCh MSc MD,
Entessar Taylouni MB BCh ABMS (Obs Gyn)*

We have compared the dose requirements and recovery characteristics of a continuous mivacurium infusion given by the anaesthetist to maintain 95–100% block at the hand muscles with that of a surgeon-controlled, on-demand dosing technique based on the direct assessment of abdominal muscle tone during elective Caesarean section. Twenty-four full term pregnant patients were included. A rapid-sequence induction using thiopentone $3\text{--}5\text{ mg}\cdot\text{kg}^{-1}$ and succinylcholine $1\text{ mg}\cdot\text{kg}^{-1}$ was used. Anaesthesia was maintained with fentanyl, N_2O and isoflurane 0.5%. The mechanomyographic response of the adductor pollicis muscle to supramaximal train-of-four (TOF) ulnar nerve stimulation was recorded. Muscle relaxation was achieved initially with mivacurium $0.1\text{ mg}\cdot\text{kg}^{-1}$ followed either by a continuous infusion of mivacurium to maintain 95–100% block at the adductor pollicis muscle ($n = 12$) or by surgeon-controlled relaxation (SCR) technique using a syringe pump for patient-controlled analgesia to administer on-demand doses of mivacurium $0.05\text{ mg}\cdot\text{kg}^{-1}$ ($n = 12$). The lockout interval was three minutes and the maximum hourly dose of mivacurium allowed was $0.6\text{ mg}\cdot\text{kg}^{-1}$. The total doses of mivacurium (mean $\pm$ SD) were 23.2 ± 10.4 and $12.4 \pm 3.5\text{ mg}$ in the infusion and SCR groups, $P < 0.01$. On-demand, surgeon-controlled doses of mivacurium were injected at a mean of T_1 $42.3 \pm 36\%$. At the end of surgery, T_1 and TOF ratio were respectively $16.7 \pm 13\%$, $5 \pm 10\%$ and $48 \pm 37\%$, $30 \pm 24\%$ in the infusion and SCR groups. Five patients in the SCR group and one patient in the infusion group did not receive antagonist at the end of surgery. The time to adequate recovery, TOF 75%, after

skin closure was 8.2 ± 2.3 and $5.3 \pm 4\text{ min}$ in the infusion and SCR groups, $P = 0.05$. It is concluded that, compared with a continuous mivacurium infusion, the SCR technique is associated with reduced mivacurium requirements, a substantial degree of neuromuscular recovery at the end of surgery and a reduced need for neostigmine reversal in full term pregnant patients undergoing elective Caesarean section.

Nous avons comparé les doses requises et les caractéristiques de la récupération obtenue après une perfusion continue de mivacurium administrée par l'anesthésiste pour maintenir la curarisation des muscles de la main à 95–100% avec une technique à demande contrôlée par le chirurgien qui évalue directement le tonus musculaire abdominal pendant la césarienne non urgente. Vingt-quatre parturientes à terme ont été admises dans cette étude. Nous avons réalisé une induction à séquence rapide au thiopentone $3\text{--}5\text{ mg}\cdot\text{kg}^{-1}$ et à la succinylcholine $1\text{ mg}\cdot\text{kg}^{-1}$. L'anesthésie a été entretenue au fentanyl-protoxyde d'azote avec de l'isoflurane 0,5%. La réponse mécanomyographique de l'adducteur du pouce à la stimulation supramaximale au train-de-quatre (TOF) du nerf cubital a été enregistrée. La myorelaxation initiale a été réalisée avec un bolus de mivacurium $0,1\text{ mg}\cdot\text{kg}^{-1}$ et par la suite soit par une perfusion de mivacurium de façon à maintenir un bloc à 95–100% de l'adducteur du pouce ($n = 12$), soit par une technique de relaxation contrôlée par le chirurgien (RCC) qui utilise une seringue automatique de type PCA pour administrer à demande des doses de mivacurium $0,05\text{ mg}\cdot\text{kg}^{-1}$ ($n = 12$). L'intervalle de sécurité a été fixé à trois min et la dose maximale horaire permise a été de $0,6\text{ mg}\cdot\text{kg}^{-1}$. Les doses totales de mivacurium (moyenne $\pm$ SD) ont été respectivement de $23 \pm 10,4$ et de $12 \pm 3,5\text{ mg}$ dans les groupes perfusion et RCC ($P < 0,01$). À demande, les doses de mivacurium injectées par le chirurgien l'ont été avec un T_1 en moyenne de $42,3 \pm 36,7\%$. À fin de la chirurgie, T_1 et la rapport du TOF étaient respectivement $16,7 \pm 13\%$, $5 \pm 10\%$ et $48 \pm 37\%$, $30 \pm 24\%$ dans les groupes perfusion et RCC. Cinq patientes du groupe RCC et une patiente du groupe perfusion n'ont pas reçu d'antagoniste à la fin de la chirurgie. L'intervalle jusqu'à la récupération adéquate, le TOF 75%, après la fermeture de la peau, a été de $8,2 \pm 2,3$ et de $5,3 \pm 4\text{ min}$ dans les groupes perfusion et RCC, $P = 0,05$. En conclusion, comparée à l'administration du mi-

Key words

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From the Department of Anaesthesia, Faculty of Medicine, Cairo University, Egypt, and the Department of Obstetrics and Gynaecology, King Fahad Hospital of the University,* Saudi Arabia.

Address correspondence to: Dr. Mohamed Abdulatif, Assistant Professor, Anaesthesiology Department, King Fahad Hospital of The University, Al-Khobar 31952, PO Box 40081, Saudi Arabia.

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vacurium en perfusion continue, la technique de RCC est associée chez la parturiente à terme opérée pour une césarienne non urgente à des besoins moindres en mivacurium, un degré important de récupération musculaire à la fin de la chirurgie et à un besoin moins important de néostigmine.

In clinical practice, the adequacy of abdominal muscle relaxation is indirectly assessed by the response of the hand muscles to supramaximal ulnar nerve stimulation. However, differences between muscles in their response to non-depolarizing neuromuscular blocking drugs have been reported frequently.¹⁻⁵ Substantial neuromuscular recovery has been reported to occur at the rectus abdominis when little or no response is evident at the hand muscles.⁶

The muscle response to peripheral nerve stimulation may be assessed accurately by the use of force displacement transducers or by electromyography.⁷⁻⁹ Unfortunately, force displacement transducers are mainly used to monitor the adductor pollicis muscle of the hand and there is no convenient point on the abdominal muscles to which a strain gauge can be connected to record its mechanical response. Any superficial muscle can be monitored by electromyography which has been used recently to compare the responses of the hand and the rectus abdominis muscles to atracurium-induced block.⁶ However, electromyography of the rectus abdominis is technically difficult during abdominal surgery, as the recording electrodes may be within the operative field.

The present study was designed to compare the dose requirements and recovery characteristics of a continuous infusion of mivacurium given by the attending anaesthetist to maintain 95–100% block at the hand muscles with an on-demand dosing technique given by the surgeon based on direct assessment of abdominal muscle tone during elective Caesarean section.

Methods

The study was approved by the Institution Research Committee and informed consent was obtained. Twenty-four full term ASA physical status I or II patients undergoing elective Caesarean section were investigated. We excluded from the study any patient suffering from cardiac, vascular, respiratory, hepatic, renal or neuromuscular disorder. Patients who deviated by >30% from expected ideal body weight and those receiving medications known to affect normal neuromuscular transmission were also excluded.

All patients received premedication with 30 ml sodium citrate 0.3 M *po* 30 minutes before induction of anaesthesia. In the operating room, lactated Ringer's solution with 5% dextrose was administered through a peripheral

arm vein to replace intraoperative fluid losses. The ECG and O₂ saturation were monitored continuously and arterial blood pressure was measured every five minutes using an electronic oscillotonometer (Dinamap).

Neuromuscular monitoring started before induction of anaesthesia. The ulnar nerve was stimulated at the wrist with square pulses of 0.2 msec duration, delivered in a train-of-four (TOF) sequence at 2 Hz repeated every ten seconds, using a Myotest peripheral nerve stimulator (Biometer International, Odense, Denmark). Supramaximal stimulation was obtained by gradual adjustment of the stimulating current over five minutes. Some of the patients felt discomfort at higher current output and were managed with the inhalation of an analgesic mixture of N₂O 50% in oxygen. The resultant contractions of the adductor pollicis muscle were recorded using a force displacement transducer and a neuromuscular function analyzer (Myograph 2000, Biometer International, Odense, Denmark). Preload tension on the thumb was maintained at 300 g throughout the investigation. After stabilization of twitch height recording, anaesthesia was induced using a standard rapid-sequence induction. After pre-oxygenation via a face mask with five litres of 100% oxygen for three to five minutes, anaesthesia was induced with thiopentone 3–5 mg · kg⁻¹ and succinylcholine 1 mg · kg⁻¹ facilitated tracheal intubation which was performed at maximum block. Anaesthesia was maintained with N₂O 60% in oxygen and isoflurane 0.5% end tidal concentration. After delivery of the baby, fentanyl, 2 µg · kg⁻¹, was administered and patients continued to receive isoflurane 0.5% until skin closure. Additional doses of fentanyl, 1 µg · kg⁻¹, were administered as required during surgery. Ventilation was controlled to maintain normocapnia (end tidal CO₂ pressure 4.6–5.3 KPa). Nasopharyngeal temperature was maintained at 36–37°C. Concentrations of isoflurane, N₂O, CO₂ and O₂ saturation were monitored by a multiple-gas analyzer (Capnomac, Datex Instrumentarium Corporation, Helsinki, Finland).

A bolus dose of mivacurium chloride 0.1 mg · kg⁻¹ was administered when the first twitch in the train-of-four response (T₁) had recovered to 75% of its control after succinylcholine. The bolus dose of mivacurium was only given after delivery of the baby and clamping of the umbilical cord. After the initial mivacurium bolus, patients were randomly allocated to one of two equal groups (*n* = 12 each). In Group 1, muscle relaxation was maintained with the use of a continuous mivacurium infusion (infusion group). Mivacurium was administered by the attending anaesthetist and was started after spontaneous recovery of T₁ to 25% of control following the initial bolus dose.

Mivacurium infusion started at a rate of 10

$\mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, and was followed by gradual adjustments to maintain 95–100% block of T_1 at the adductor pollicis muscle. Mivacurium infusion was discontinued after closure of the rectus abdominis sheath. In Group 2, intraoperative muscle relaxation was provided by the surgeon (SCR group). A syringe pump, originally designed for patient-controlled analgesia (Graseby 3300 PCA pump, Graseby Medical, UK), was used. The use of the PCA pump and the clinical profile of mivacurium chloride were explained to the surgeon who participated in the investigation. The PCA pump was programmed to deliver small incremental on-demand doses of mivacurium $0.05 \text{ mg} \cdot \text{kg}^{-1}$ over one minute. The lockout interval between the on-demand doses was three minutes, and the maximum hourly dose of mivacurium allowed was $0.6 \text{ mg} \cdot \text{kg}^{-1}$. The patient handset piece of the PCA pump was inserted under the surgical sterile drapes and was made available to the surgeon near the operative field. The degree of intraoperative muscle relaxation was directly assessed by the surgeon every five minutes. The surgeon was instructed to press the patient handset of the pump whenever he felt increased tone of the abdominal muscles sufficient to interfere with the surgical procedure. An improvement in the tone of abdominal muscles was expected within two to three minutes after injection. On-demand mivacurium administration was available to the surgeon immediately after the injection of the initial bolus until the time of rectus sheath closure. The undiluted preparation of mivacurium chloride $2 \text{ mg} \cdot \text{ml}^{-1}$ was used for the continuous infusion and for the SCR groups.

At the end of the surgery, the depth of residual mivacurium-induced block was assessed and the choice of reversal vs spontaneous recovery was decided. When the four responses of the TOF were present and a TOF ratio (the fractional height of the fourth twitch in relation to the first twitch in the train-of-four response (T_4/T_1)) of 40% or more was recorded at the time of skin closure, spontaneous recovery was allowed. Otherwise, neostigmine 2.5 mg combined with atropine 1.2 mg was used to antagonise residual block. If 100% block was still present at the time of skin closure, administration of neostigmine was delayed until spontaneous recovery of T_1 to 10% of control. Adequate recovery was indicated by the recovery of TOF ratio to 75%.¹⁰

The muscle response to succinylcholine, mivacurium and neostigmine was recorded and the following variables were determined: (1) onset of block: time interval between the end of injection of the bolus dose of succinylcholine or mivacurium and the development of maximum block, (2) time to 25 and 75% recovery of T_1 after succinylcholine administration, (3) recovery index of succinylcholine: time interval between 25% and 75% recovery of T_1 , (4) time

required for T_1 to recover to 25% of its control (clinical duration) after the initial or the on-demand surgeon controlled doses of mivacurium, (5) depth of neuromuscular block (T_1 height and TOF ratio) at which on-demand surgeon-controlled doses were required, (6) depth of block at the time of complete skin closure, (7) time interval between skin closure and adequate recovery of neuromuscular functions (TOF 75%), (8) mivacurium requirement in each patient: the total dose of mivacurium consumed during surgery (initial bolus plus the dose given by infusion or by the surgeon), (9) the time interval during which mivacurium was administered by the attending anaesthetist or was available for administration by the surgeon (duration mivacurium). Clinically, this time interval coincided with the time between the end of injection of the initial bolus dose of mivacurium and closure of the rectus sheath.

Peripheral venous samples were taken from all patients before induction of anaesthesia for measurement of plasma cholinesterase activity. The normal range in our population is $3\text{--}7 \text{ U} \cdot \text{ml}^{-1}$.

Student's *t* test, Chi-square and Fisher's exact tests were used, as appropriate, to compare data in the two groups. All results will be expressed as means $\pm$ SD (range) and a *P* value <0.05 was considered significant.

Results

Patients in the two groups were comparable with respect to age, weight, height, duration of surgery and number of full-term pregnancies. Plasma cholinesterase activity was slightly reduced in the two groups (Table I). All surgical procedures were performed by the same surgeon.

The onset time and recovery variables from succinylcholine-induced block were comparable in the two groups (Table II). Complete suppression of the four responses of the TOF (100% block) was produced by the initial dose of mivacurium in all patients. The clinical duration of the initial bolus of mivacurium and the time interval during which mivacurium was administered by the attending anaesthetist or was available for administration by the surgeon (duration mivacurium) were similar in the two groups. The total mivacurium requirements were 23.2 ± 10.4 and $12.4 \pm 3.5 \text{ mg}$ in the infusion and SCR groups, respectively, $P < 0.01$ (Table II).

Usually, one to two on-demand surgeon-controlled doses of mivacurium were required to maintain relaxation. One patient in the SCR group did not require any on-demand surgeon-controlled doses of mivacurium during surgery and this patient had normal plasma cholinesterase activity. The duration of surgery and the time to 25% T_1 recovery after the initial bolus dose of mivacurium in this patient, were 51 and 13.3 minutes, respectively, and were comparable with other patients. In

TABLE I Patients characteristics (mean $\pm$ SD (range))

Group (n = 12 each)	Age (yr)	Weight (kg)	Height (cm)	Number of Full-term pregnancies	Duration of surgery (min)	Plasma cholin- esterase activity (U· ml ⁻¹)
Infusion	31.3 $\pm$ 5.6 (21–40)	66.5 $\pm$ 8.4 (48–77)	161 $\pm$ 3.3 (154–168)	4.0 $\pm$ 2.7 (1–11)	62.6 $\pm$ 11.4 (52–76)	2.6 $\pm$ 0.7 (1.1–4.2)
SCR	29.5 $\pm$ 3.3 (25–34)	71.1 $\pm$ 5.9 (64–82)	163 $\pm$ 5.2 (155–171)	4.5 $\pm$ 3.1 (1–11)	65.6 $\pm$ 13.4 (51–96)	2.7 $\pm$ 0.8 (1–4.7)

SCR = Surgeon-controlled relaxation.

TABLE II Neuromuscular characteristics of succinylcholine and mivacurium-induced block (mean $\pm$ SD (range))

Group (n = 12)	Succinylcholine-induced block				Mivacurium-induced block			
	Onset (sec)	T ₁ 25% (min)	T ₁ 75% (min)	Recovery index (min)	Initial bolus		Duration mivacurium (min)	Total mivacurium requirements (mg)
					Onset (sec)	T ₁ 25% (min)		
Infusion	41.6 $\pm$ 10.5 (30–70)	8.0 $\pm$ 2.3 (5.4–11)	10.3 $\pm$ 2.4 (6.6–12.5)	2.3 $\pm$ 0.3 (1.2–3.2)	87.5 $\pm$ 30 (30–140)	14.6 $\pm$ 4.3 (7.4–19)	40.3 $\pm$ 10.3 (26–55)	23.2 $\pm$ 10.4 (19–43.7)
SCR	40.1 $\pm$ 9.7 (25–58)	9.8 $\pm$ 2.6 (5.8–13)	12.0 $\pm$ 2.8 (7.5–16)	2.1 $\pm$ 0.4 (1.7–2.9)	69.6 $\pm$ 18 (52–120)	16.1 $\pm$ 6.7 (9–21.5)	43.2 $\pm$ 12 (32–72)	12.4 $\pm$ 3.5* (8–17.9)

SCR = Surgeon-controlled relaxation.

*Significantly different from the other group ($P < 0.01$).TABLE III Neuromuscular characteristics of the surgeon-controlled relaxation group (mean $\pm$ SD (range))

Time (minutes)			Depth of block at the time of administration of on-demand doses		
Interval between initial bolus and first surgeon on-demand dose	Interval between surgeon on-demand doses	Number of surgeon on-demand doses	Number of twitches	T ₁ 1%	TOF ratio (%)
23 $\pm$ 9.9 (13–37)	24 $\pm$ 2.3 (22–26)	1.5 $\pm$ 0.9 (0–3)	2.3 $\pm$ 1.6 (0–4)	42.3 $\pm$ 36 (0–95)	20 $\pm$ 30 (0–85)

contrast, one other patient in the same group required three on-demand surgeon-controlled doses of mivacurium. This patient was the only primigravida included in this study. The mean T₁ height at the adductor pollicis at which on-demand surgeon-controlled doses were required was 42.3 $\pm$ 36% of the control. On-demand surgeon-controlled doses were sufficient to induce 100% neuromuscular block in all patients in the SCR group, regardless of the degree at which they were administered. The clinical duration of on-demand surgeon-controlled doses of mivacurium was 11.8 $\pm$ 5.4 min. The details of neuromuscular parameters of the SCR group are presented in Table III.

At the time of skin closure, the T₁ and TOF ratio were, respectively, 16.7 $\pm$ 13%, 5 $\pm$ 10% and 48 $\pm$ 37%, 30 $\pm$ 24% in the infusion and SCR groups, $P < 0.05$.

The times required for adequate neuromuscular recovery (TOF = 75%) after complete skin closure were 8.2 $\pm$ 2.2 and 5.3 $\pm$ 4 min in the infusion and SCR groups, respectively, $P = 0.05$. Five patients (42%) in the SCR group had a TOF ratio of $\geq 40\%$ at the time of skin closure and did not require the use of antagonist. Two of these patients had TOF ratio $\geq 75\%$ at the end of surgery. In contrast, 11 patients (91%) in the infusion group had TOF $< 40\%$ at the end of surgery and required the use of antagonist (Table IV). In two patients in each group, 100% neuromuscular block was present in the hand muscles at the time of complete skin closure. In these patients, neostigmine administration was delayed for 1–3.5 min until spontaneous recovery to 10% T₁ was recorded. After neostigmine administration, a TOF ratio of 75% was obtained within four to eight minutes.

TABLE IV Depth of block (mean $\pm$ SD (range)) and mode of recovery at the end of surgery

Group (<i>n</i> = 12 each)	<i>T</i> ₁ height at the end of surgery (% of control)	TOF ratio at the end of surgery (<i>T</i> ₄ / <i>T</i> ₁ %)	Time in minutes to adequate recovery (TOF 75%)	Number of patients who required neostigmine	Number of patients spontaneously recovered	Number of patients with TOF 75% or more at the end of surgery
Infusion	16.7 $\pm$ 13 (0-60)	5 $\pm$ 10 (0-58)	8.2 $\pm$ 2.2 (3-11)	11(91%)	1(9%)	0
SCR	48 $\pm$ 37* (0-100)	30 $\pm$ 24* (0-84)	5.3 $\pm$ 4 (0-10.4)	7(58%)	5(42%)	2(16%)

SCR = Surgeon-controlled relaxation.

*Significantly different from other group ($P < 0.05$).

Discussion

In the non-pregnant patient, abdominal muscles require larger doses of neuromuscular blockers to achieve the same degree of block at the hand muscles.⁶ A twitch height $<10\%$ control at the hand muscles is frequently quoted as the level of block associated with adequate abdominal muscle relaxation.^{7,11} However, there are not sufficient data in the literature to support this contention. In the present study, using a SCR technique, we have tried to relate the dose requirements of non-depolarizing neuromuscular blocking agents to the tone of abdominal muscles. The surgeon administered incremental doses of mivacurium whenever his work was hindered by the increased tone in the abdominal muscles during elective Caesarean section. The doses of mivacurium given by the SCR technique were compared with doses given by the anaesthetist to maintain a twitch height of 5% or less at the hand muscles. Further, the critical level of block at the hand muscles at which abdominal relaxation was judged as inadequate by the surgeon was determined. The findings of the present study demonstrated that, in the full-term pregnant patient undergoing elective Caesarean section, sufficient abdominal muscle relaxation may be present despite substantial degrees of neuromuscular recovery at the hand muscles. In the SCR group, the surgeon felt increased tone in the abdominal muscles requiring relaxation when the mean *T*₁ height at the adductor pollicis muscle was $42.3 \pm 36\%$. The total dose of mivacurium required for satisfactory abdominal relaxation in the SCR group was 12.4 ± 3.5 mg. This was less than the total dose given by the attending anaesthetist, in the continuous infusion group (23.2 ± 10.4 mg). These findings may appear surprising; however, during late pregnancy, the muscles of the abdominal wall become stretched to accommodate the enlarging uterus. With repeated pregnancy, thinning of the abdominal muscles with reduction of its tone is a common finding.^{12,13} During Caesarean section, after delivery of the infant, the stretched and weak abdominal muscles lose the splinting action of the gravid uterus and sag offering less resistance

to the surgeon. Most of our patients had had repeated full-term pregnancies (average of four), and this may have caused weakness of the abdominal muscles, which would account for the reduced dose requirements of mivacurium in the SCR group.

Reduction of mivacurium requirements in the SCR group was associated with greater spontaneous recovery at the time of skin closure and a shorter time to adequate neuromuscular recovery. These findings confirm that the surgeon did not abuse the advantage of on-demand surgeon-controlled dosing technique during Caesarean section. Our previous experience with spontaneous recovery from mivacurium-induced neuromuscular block during isoflurane anaesthesia has shown that train-of-four recovery proceeds at a rate of $6-7\% \cdot \text{min}^{-1}$.¹⁴ This implies that, at the end of surgery, if spontaneous recovery from mivacurium-induced block had reached a level of 40%, about five to six minutes are usually required for adequate recovery (TOF 75%) without the use of antagonist. We have considered this time interval clinically convenient to allow continued spontaneous recovery in those patients reaching this degree of neuromuscular recovery (TOF 40%), at the end of surgery. Five of the 12 patients (42%) in the SCR group had a TOF ratio $\geq 40\%$ at the time of skin closure and the block was allowed to recover spontaneously. This was the cause for the reduced need for neostigmine antagonism in the SCR group. The use of neostigmine-atropine mixtures has been reported to cause reduction in lower oesophageal sphincter tone¹⁵ and to increase the incidence of post-operative nausea and vomiting.¹⁶ Therefore, avoiding or reducing the use of neostigmine may be desirable in full-term pregnant patients who have reduced tone of the lower oesophageal sphincter and are at increased risk of regurgitation and aspiration.

We preferred to use mivacurium chloride in the present study because it is non-cumulative and has a predictable duration of action.¹⁷ Further, it has been demonstrated that once recovery from mivacurium block is underway, it occurs at a rate which is independent of the dose or

the duration of administration.¹⁷ The size of on-demand mivacurium doses was chosen to be equivalent to the ED₉₅ during isoflurane anaesthesia¹⁸ and was sufficient to achieve 100% block in all patients. The lock-out interval between on-demand doses was adjusted at three minutes to allow rapid titration to the desired degree of abdominal relaxation in a reasonable time. The maximum hourly dose of mivacurium was derived from the manufacturer's dosage recommendation during isoflurane anaesthesia (0.5–0.6 mg · kg⁻¹ · hr⁻¹).

The results of the present study also confirmed that although plasma cholinesterase activity is reduced during pregnancy, the magnitude of this reduction is not sufficient to prolong the duration of action of succinylcholine.^{19,20} Both study groups had clinical durations of succinylcholine comparable with non-pregnant patients.²¹ Like succinylcholine, mivacurium chloride is hydrolyzed by plasma cholinesterase.^{17,22} Patel *et al.* reported recently that the response to mivacurium-induced block in the postpartum period is not different from the non-pregnant patient.²³ Similarly, the clinical duration of the initial bolus dose of mivacurium in the present study was comparable to the values reported with the use of the same dose in the non-pregnant patient.¹⁷ This suggests that the clinical course of mivacurium-induced block is predictable in the pregnant patient and is not prolonged by the slight reduction in plasma cholinesterase activity. In contrast to mivacurium, the clinical duration of vecuronium-induced block is prolonged and the requirements are reduced in the pregnant and postpartum patient.^{24,25}

In conclusion, we have demonstrated that maintenance of mivacurium-induced neuromuscular block during elective Caesarean section could be achieved with the use of an on-demand SCR technique guided by the direct assessment of abdominal muscle tone. Compared with a continuous infusion given by the attending anaesthetist to maintain 95–100% at the hand muscles, the SCR technique was associated with reduced mivacurium requirement, a substantial degree of neuromuscular recovery at the end of surgery, a shorter time to adequate recovery, and a reduced need for neostigmine antagonism. It is to be noted, however, that our findings apply only to full-term pregnant patients undergoing Caesarean section. Higher doses of mivacurium may be required with the use of the SCR technique for other types of abdominal surgery. For a safe and successful outcome of the SCR technique, the doses and lock-out intervals should be carefully determined in view of the duration of surgery, the pharmacokinetic and pharmacodynamic profiles of the neuromuscular blocking agent used. Further studies are required to assess the safety and effectiveness of the SCR technique.

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References

- 1 Donati F, Antzaka C, Bevan DR. Potency of pancuronium at the diaphragm and the adductor pollicis muscle in humans. *Anesthesiology* 1986; 65: 1–5.
- 2 Chauvin M, Lebrault C, Duvaldestin P. The neuromuscular blocking effect of vecuronium on the human diaphragm. *Anesth Analg* 1987; 66: 117–22.
- 3 Derrington MC, Hindocha N. Comparison of neuromuscular block in the diaphragm and hand after administration of tubocurarine, pancuronium and alcuronium. *Br J Anaesth* 1990; 64: 294–9.
- 4 Donati F, Meistelman C, Plaud B. Vecuronium neuromuscular blockade at the diaphragm, the orbicularis oculi, and adductor pollicis muscles. *Anesthesiology* 1990; 73: 870–5.
- 5 Donati F. Sensitivity of different muscles to neuromuscular blocking drugs. *Current Opinion in Anaesthesiology* 1991; 4: 593–8.
- 6 Sessler JM, Marks LF, Norman J. Comparison of atracurium-induced neuromuscular block in rectus abdominis and hand muscles of man. *Br J Anaesth* 1992; 69: 26–8.
- 7 Viby-Mogensen J. Clinical assessment of neuromuscular transmission. *Br J Anaesth* 1982; 54: 209–23.
- 8 Rupp SM. Monitoring neuromuscular blockade. Twitch monitoring. *Anesthesiology Clinics of North America* 1993; 11: 361–78.
- 9 Meistelman C. Monitoring of neuromuscular transmission. *Current Opinion in Anaesthesiology* 1993; 6: 720–5.
- 10 Brand JB, Cullen DJ, Wilson NE, Ali HH. Spontaneous recovery from nondepolarizing neuromuscular blockade: correlation between clinical and evoked response. *Anesth Analg* 1977; 56: 55–8.
- 11 Brull SJ, Silverman DG. Intraoperative use of muscle relaxants. *Anesthesiology Clinics of North America* 1993; 11: 325–44.
- 12 Normal pregnancy: physiology and management. In: Dewhurst J (Ed.). *Integrated Obstetric and Gynaecology for Postgraduates*, 3rd ed, London: Blackwell Scientific Publication, 1981; 103–34.
- 13 Anatomy and physiology. In: Lewis TLT, Chamberlain GVP (Eds.). *Obstetrics by Ten Teachers*, 15th ed, London: Edward Arnold, 1990; 1–32.
- 14 Naguib M, Abdulatif M, Al-Ghamdi A, Hamo I, Nouheid R. Dose-response relationships for edrophonium and neostigmine antagonism of mivacurium-induced neuromuscular block. *Br J Anaesth* 1993; 71: 709–14.
- 15 Turner DAB, Smith G. Evaluation of the combined effects of atropine and neostigmine on the lower oesophageal sphincter. *Br J Anaesth* 1985; 57: 956–9.

- 16 King MJ, Milazkiewicz R, Carli F, Deacock AR. Influence of neostigmine on postoperative vomiting. *Br J Anaesth* 1988; 61: 403-6.
- 17 Savarese JJ, Ali HH, Basta SJ, et al. The clinical neuromuscular pharmacology of mivacurium chloride (BW B1090U): a short acting nondepolarizing ester neuromuscular blocking drug. *Anesthesiology* 1988; 68: 723-32.
- 18 Weber S, Brandom B, Powers DM, et al. Mivacurium chloride (BW B1090U)-induced neuromuscular blockade during nitrous oxide-isoflurane and nitrous oxide-narcotic anaesthesia in adult surgical patients. *Anesth Analg* 1988; 67: 495-9.
- 19 Blitt CD, Petty WC, Alberternst EE, Wright BJ. Correlation of plasma cholinesterase activity and duration of action of succinylcholine during pregnancy. *Anesth Analg* 1977; 56: 78-83.
- 20 Baraka A, Noueihed R, Sinno H, Wakid N, Agoston S. Succinylcholine-vecuronium (Org NC 45) sequence for cesarean section. *Anesth Analg* 1983; 62: 909-13.
- 21 Magorian T, Flannery KB, Miller RD. Comparison of rocuronium, succinylcholine, and vecuronium for rapid-sequence induction of anesthesia in adult patients. *Anesthesiology* 1993; 79: 913-8.
- 22 Cook DR, Stiller RL, Weakly JN, Chakravorti S, Brandom BW, Welch RM. In vitro metabolism of mivacurium chloride (BW B1090U) and succinylcholine. *Anesth Analg* 1989; 68: 452-6.
- 23 Patel R, Katz R, Martinez V, Foster S, Azad A, Calmes S. Effects of mivacurium-induced neuromuscular blockade in the postpartum patient. *Anesthesiology* 1993; 79: A967.
- 24 Baraka A, Jabbour S, Tabboush Z, Sibai A, Bijjani A, Karam K. Onset of vecuronium neuromuscular block is more rapid in patients undergoing Caesarean section. *Can J Anaesth* 1992; 39: 135-8.
- 25 Camp CE, Tessem J, Adenwala J, Joyce TH. Vecuronium and prolonged neuromuscular blockade in postpartum patients. *Anesthesiology* 1987; 67: 1006-8.