Electromyographic assessment of neuromuscular block at the gastrocnemius muscle†

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We have assessed neuromuscular block electromyographically at the gastrocnemius muscle and compared it with that at the abductor digiti minimi muscle in 60 adult patients undergoing cervical spine surgery under general anaesthesia. All patients were in the prone position. After vecuronium 0.2 mg kg–1, times to onset of neuromuscular block at the gastrocnemius and abductor digiti minimi muscles were mean 147 (SD 24) and 145 (14) s, respectively (ns). Times to return of the first response of the post-tetanic count (PTC1) at the gastrocnemius and abductor digiti minimi muscles were 27.7 (5.6) and 37.0 (5.9) min, respectively (P<0.0001).

Times to return of the first response of the train-of-four (TOF) at the gastrocnemius and abductor digiti minimi muscles were 41.0 (9.1) and 49.9 (8.7) min, respectively (P<0.01).

Recovery of PTC, T1/T0 and TOF ratio at the gastrocnemius muscle were significantly faster than at the abductor digiti minimi muscle.


Keywords: neuromuscular block, vecuronium; monitoring, neuromuscular block; measurement techniques, electromyography; muscle skeletal, gastrocnemius

Accepted for publication: August 17, 1998

The degree of neuromuscular block is commonly evaluated at the thumb. However, during ear, nose and throat, ophthalmological, neurosurgical or some orthopaedic surgical procedures, the arms of the patient may lie alongside the trunk. The level of neuromuscular block cannot then be assessed easily using a force or accelerographic transducer at the thumb. But it can be quantified at the great toe using accelerography.1–4 However, during orthopaedic surgery of the cervical spine, accelerographic monitoring cannot be performed as patients are held in a prone position and the feet are fixed on an operating bed. No previous study has investigated the response at the gastrocnemius muscle electromyographically during anaesthesia, nor has neuromuscular monitoring been studied with a patient in the prone position. We have evaluated neuromuscular block electromyographically at the gastrocnemius muscle and compared it with that at the abductor digiti minimi muscle during posterior fusion of the cervical spine.

Patients and methods

We studied 60 adult patients, ASA I or II, undergoing elective orthopaedic surgery of the cervical spine (posterior fusion) under general anaesthesia. The study was approved by our Local Ethics Committee, and written informed consent was obtained from each subject. No patient had neuromuscular, cardiac, hepatic or renal disorders, or was receiving any drug known to interfere with neuromuscular transmission. Patients were divided into four groups (n=15 each): G-PTC, A-PTC, G-TOF and A-TOF (G=gastrocnemius muscle, A=abductor digiti minimi muscle, PTC=post-tetanic count and TOF=train-of-four).

Premedication comprised atropine 0.01 mg kg–1 and hydroxyzine 1.0 mg kg–1 i.m., 30 min before induction of anaesthesia. In the operating theatre, in the G-PTC and G-TOF groups, two surface stimulating electrodes (Vitrodes, Nihon-Kohden Inc., Tokyo, Japan) were positioned over the tibial nerve at the popliteal fossa, and another two surface recording electrodes over the lateral head of the gastrocnemius muscle. To keep the gastrocnemius and abductor digiti minimi muscles warm, the leg and hand were covered by towels. Peripheral temperature over the gastrocnemius and abductor

†This article is accompanied by Editorial III.
digitii minimi muscles was monitored using a surface skin thermometer (Terumo-Finer, Nihon-Kohden Inc., Tokyo, Japan).

In each group, after administration of propofol 2.0 mg kg\(^{-1}\) i.v., train-of-four (TOF) stimuli were given at 50 mA every 12 s over the tibial or ulnar nerve, each stimulus consisting of a 0.2 ms duration square wave at a frequency of 2 Hz. The corresponding electromyographic response at the gastrocnemius or abductor digitii minimi muscle was amplified (Isolator, Nihon-Kohden Inc., Tokyo, Japan). The electromyographic signals were displayed on an oscilloscope (Memory Oscilloscope, Nihon-Kohden Inc., Tokyo, Japan), and electromyographic amplitudes were stored on the hard disc of a personal computer (PC-9801 UX, NEC Inc., Tokyo, Japan).

We ensured that a supramaximal response could be obtained at a stimulating current of 50 mA in each patient. After recording a control value (TO), vecuronium 0.2 mg kg\(^{-1}\) was administered i.v. to facilitate tracheal intubation. Time from vecuronium injection to disappearance of the electromyographic response to the first twitch of the TOF (T1) was defined as onset time. Onset times were compared between the G-TOF and A-TOF groups. In each group, anaesthesia was maintained with 1.0% end-tidal isoflurane concentration and 66% nitrous oxide in oxygen, and patients’ lungs were ventilated to maintain normocapnia (\(P_{\text{ET}}CO_2\) 4.2–5.0 kPa) throughout the surgical procedure. End-tidal anaesthetic concentrations and \(P_{\text{ET}}CO_2\) were measured using a multiple gas monitor (Capnomac Ultima, Datex Inc., Helsinki, Finland).

In the G-PTC and A-PTC groups, during spontaneous recovery from neuromuscular block, post-tetanic twitch (PTT) stimuli were delivered every 5 min after injection of vecuronium. A 50-Hz tetanic stimulation of 5 s duration was applied at 50 mA. After a pause of 3 s, 30 single twitch square wave stimuli of 0.2 ms duration were given at intervals of 1 s. Electromyographic amplitude in response to the single twitch stimuli of the PTT was recorded in the same manner as for TOF. Single twitch responses in the PTT were regarded as detectable when the electromyographic responses reached 1% of control. This method of detection of single twitch stimuli was also used in our previous study.\(^5\)

The number of detectable electromyographic responses to single twitch stimuli delivered after tetanic stimulation was defined as the post-tetanic count (PTC). In this way, PTC were measured every 5 min in the two groups. Times to return of PTC1 (the first post-tetanic twitch) and the time course of recovery of PTC were compared between the two groups.

In the G-TOF and A-TOF groups, during spontaneous recovery from neuromuscular block, TOF stimuli were given every 12 s. Times from vecuronium injection to return of T1, T2, T3 and T4 of the TOF were compared between the two groups. T1, T2, T3 and T4 were regarded as present when T1/T0, T2/T0, T3/T0 and T4/T0 reached 1%. The time courses of recovery of T1/T0 and TOF ratio (T4/T1) were also compared between the two groups.

Patient characteristics were compared between the four groups using analysis of variance (ANOVA) followed by Scheffe’s \(F\) test. For comparison of the onset times of neuromuscular block and times to return of PTC1, T1/T0, T2/T0, T3/T0 and T4/T0, an unpaired \(t\) test was used. Time courses of recovery of PTC were compared using the Mann–Whitney \(U\) test followed by Bonferroni’s adjustment. Time courses of recovery of T1/T0 and TOF ratios were compared using an unpaired \(t\) test and Bonferroni’s adjustment. \(P<0.05\) was considered statistically significant. Statistical analyses were performed using a statistical package, STAT FLEX version 2 (Viewflex Inc., Tokyo, Japan) running on a personal computer (PC 9821 Ne, NEC Inc., Tokyo, Japan).

Results

Patient characteristics were comparable in the four groups (Table 1).

Time to onset of neuromuscular block in group G-TOF did not differ significantly from that in group A-TOF (mean 147 (sd 24) vs 145 (14) s).

Times to return of PTC1, T1/T0, T2/T0, T3/T0 and T4/T0 at the gastrocnemius muscle were significantly shorter than at the abductor digitii minimi muscle (Table 2). PTC in group G-PTC was significantly greater than that in group A-PTC, 30–45 min after injection of vecuronium (Fig. 2). T1/T0 and TOF ratios in group G-TOF were significantly greater than those in group A-TOF, 80–180 min after administration of vecuronium (Figs 3, 4).
Neuromuscular block at the gastrocnemius muscle

Table 1 Physical characteristics (number or mean (SD or range)). G=Gastrocnemius muscle, A=abductor digiti minimi muscle, PTC=post-tetanic count, TOF=train-of-four. Patient characteristics did not differ between the four groups

<table>
<thead>
<tr>
<th>Group</th>
<th>G-PTC</th>
<th>A-PTC</th>
<th>G-TOF</th>
<th>A-TOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>7/8</td>
<td>7/8</td>
<td>7/8</td>
<td>7/8</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>45.9 (22–75)</td>
<td>47.0 (28–73)</td>
<td>46.8 (29–78)</td>
<td>48.1 (23–77)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166.9 (8.5)</td>
<td>166.4 (9.0)</td>
<td>167.4 (6.9)</td>
<td>166.1 (6.3)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>56.0 (5.5)</td>
<td>56.8 (6.2)</td>
<td>55.7 (7.1)</td>
<td>57.4 (6.4)</td>
</tr>
</tbody>
</table>

Table 2 Times from administration of vecuronium 0.2 mg kg⁻¹ to return of PTC1 at the gastrocnemius muscle (G-PTC group) and at the abductor digiti minimi muscle (A-PTC group), and those of T1–4 at the gastrocnemius muscle (G-TOF group) and at the abductor digiti minimi muscle (A-TOF group) (mean (SD)). Return of PTC1 and T1–4 were significantly faster in the G-PTC and G-TOF groups than in the A-PTC and A-TOF groups

<table>
<thead>
<tr>
<th>Gastrocnemius</th>
<th>Abductor digiti minimi</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTC1 (min)</td>
<td>27.7 (5.6)</td>
<td>37.0 (5.9)</td>
</tr>
<tr>
<td>T1 (min)</td>
<td>41.0 (9.1)</td>
<td>49.9 (8.7)</td>
</tr>
<tr>
<td>T2 (min)</td>
<td>51.3 (8.0)</td>
<td>63.3 (11.6)</td>
</tr>
<tr>
<td>T3 (min)</td>
<td>54.9 (7.9)</td>
<td>71.6 (14.2)</td>
</tr>
<tr>
<td>T4 (min)</td>
<td>57.5 (8.0)</td>
<td>75.5 (14.3)</td>
</tr>
</tbody>
</table>

Discussion

We have shown that neuromuscular block can be assessed electromyographically at the gastrocnemius muscle. After administration of vecuronium 0.2 mg kg⁻¹, onset of block at the gastrocnemius muscle was similar to that at the abductor digiti minimi muscle. However, recovery from neuromuscular block at the gastrocnemius muscle occurred more rapidly than that at the abductor digiti minimi muscle. Hence electromyographic monitoring of neuromuscular block at the gastrocnemius muscle was more useful in assessing profound neuromuscular block than at the abductor digiti minimi muscle.

It has been reported that at the great toe, onset of neuromuscular block caused by vecuronium was slower than that at the thumb, and recovery was faster.¹ ² These results could be related to the fact that the flexor hallucis brevis muscle contains more type-2 fibres than the adductor pollicis muscle,⁶ and that the type-2 muscle fibre is more resistant to non-depolarizing neuromuscular blocking drugs than the type-1 muscle fibre.¹ ³ ⁴ It also has been shown that the gastrocnemius muscle contains more type-2 fibres than

Fig 2 Post-tetanic count (PTC) obtained in the G-PTC and A-PTC groups at 5-min intervals after injection of vecuronium. G=Gastrocnemius muscle, A=abductor digiti minimi muscle. *P<0.05 between groups.

Fig 3 T1/T0 in the G-TOF and A-TOF groups at 20-min intervals after injection of vecuronium. G=Gastrocnemius muscle, A=abductor digiti minimi muscle, TOF=train-of-four. *P<0.05 between groups.

Fig 4 TOF ratios obtained in the G-TOF and A-TOF groups at 20-min intervals after injection of vecuronium. G=Gastrocnemius muscle, A=abductor digiti minimi muscle, TOF=train-of-four. *P<0.05 between groups.
the abductor digiti minimi muscle. For this reason, it could be expected in this study that recovery of neuromuscular block at the gastrocnemius muscle would be faster than that at the abductor digiti minimi muscle. However, the onset of neuromuscular block at the gastrocnemius muscle did not differ significantly from that at the abductor digiti minimi muscle. The dose of vecuronium in our study (0.2 mg kg\(^{-1}\)) was more than 10 times as high as the ED\(_{90}\) during isoflurane anaesthesia.\(^7\) Wright, Caldwell and Miller\(^8\) reported that onset of effect with rocuronium 0.4 mg kg\(^{-1}\) at the laryngeal adductor muscle was significantly more rapid than at the adductor pollicis muscle. Nevertheless, in their study, the difference in onset times at the two muscles became more similar as the dose of rocuronium was increased. Thus our finding that the times to onset of neuromuscular block at the gastrocnemius and abductor digiti minimi muscles were identical might be attributable to the relatively high dose of vecuronium used.

We have shown that after administration of vecuronium, return of T\(_1\)/T\(_0\) at the gastrocnemius muscle was 8.9 min faster than at the abductor digiti minimi muscle. This time interval is comparable with that between return of T\(_1\)/T\(_0\) at the diaphragm and at the adductor pollicis muscle after administration of vecuronium (7.7 min).\(^9\) In our study, when T\(_1\)/T\(_0\) at the gastrocnemius muscle was 0.4, T\(_1\)/T\(_0\) at the abductor digiti minimi muscle was approximately 0.2 (Fig. 2). Donati, Meistelman and Plaud\(^10\) demonstrated that during spontaneous recovery from neuromuscular block produced by vecuronium, when T\(_1\)/T\(_0\) at the diaphragm was approximately 0.4, T\(_1\)/T\(_0\) at the adductor pollicis muscle was approximately 0.2. Engbaek and Roed\(^11\) demonstrated that sensitivity to pancuronium was similar between the adductor pollicis and abductor digiti minimi muscles. If the time courses of recovery from neuromuscular block at the adductor pollicis and abductor digiti minimi muscles are comparable, recovery of neuromuscular block at the gastrocnemius muscle and the diaphragm may follow a similar time course.

We compared the sensitivity of the gastrocnemius muscle to vecuronium with that of the adductor digiti minimi muscle. No previous study has investigated the relative sensitivities of these two muscles to other non-depolarizing neuromuscular blocking drugs. But Laycock and colleagues\(^12\) examined the sensitivity of the diaphragm compared with the adductor pollicis muscle after atracurium and vecuronium, and showed that both drugs exhibited a similar degree of sparing of the diaphragm. Consequently, the difference between the sensitivity of the gastrocnemius muscle and the adductor digiti minimi muscle may occur with other neuromuscular blocking drugs.

In several previous studies,\(^1,4\)\(^10\)\(^-\)\(^12\) onset or recovery of neuromuscular block at different muscles was examined after administration of non-depolarizing neuromuscular blocking drugs. However, few studies\(^8\)\(^9\) have investigated onset or recovery of neuromuscular block caused by depolarizing neuromuscular blocking drugs at different muscles. Wright, Caldwell and Miller\(^8\) showed that onset of succinylcholine 1.0 mg kg\(^{-1}\) at the laryngeal adductor muscle was more rapid than at the adductor pollicis muscle, and this was also true for rocuronium 0.4 mg kg\(^{-1}\).

We believe that during orthopaedic surgery of the cervical spine, the degree of neuromuscular block can be evaluated easily electromyographically at the gastrocnemius or adductor digiti minimi muscle. However, if the adductor digiti minimi muscle is used, in some patients, bucking or coughing can be observed, even at a PTC of zero.\(^5\) To ensure sufficiently deep neuromuscular block, electromyographic monitoring at the gastrocnemius muscle would be preferable.

References

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