TOF count at corrugator supercilii reflects abdominal muscles relaxation better than at adductor pollicis†

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Background. A recovery profile from neuromuscular block similar to that of abdominal (AB) muscles, but different to that of the adductor pollicis (AP) muscle, has been demonstrated at the corrugator supercilii (CSC) muscle. We hypothesized that neuromuscular transmission (NMT) monitoring of CSC might provide useful information on AB relaxation compared with AP. We compared the visual estimation of NMT at CSC and AP with electromyographic measurements of AB during recovery from a vecuronium block.

Methods. Ten adult patients were studied during balanced anaesthesia. After induction of anaesthesia and tracheal intubation without neuromuscular blocking agents, supramaximal stimulations were applied to three nerves: left 10th intercostal, ulnar, and facial. Electro-myographic activity (EMG) of AB was measured (ABEMG). After a bolus dose of vecuronium 0.1 mg kg⁻¹, an independent observer blinded to the EMG measurements counted visually detectable train-of-four (TOF) responses at CSC and AP. Values of ABEMG associated with 1 to 4 TOF responses at CSC and AP were compared. Values are means (SD).

Results. Reappearance of the first and second TOF responses at CSC occurred significantly (P<0.05) earlier and at lower ABEMG recovery than that of AP [35 (8) and 41 (9) min vs 51 (10) and 56 (12) min; and 17 (8) and 26 (9)% vs 56 (10) and 75 (11)%], respectively.

Conclusions. We demonstrated that the TOF response count at the CSC, compared with the AP, allowed a better quantification of the degree of AB muscle relaxation during recovery from vecuronium block.

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The concept of relative sensitivity or resistance of certain muscle groups to neuromuscular blocking agents (NMBA) supports the rationale for neuromuscular transmission (NMT) monitoring during anaesthesia. Peripheral muscles such as the adductor pollicis (AP) muscle and some pharyngeal muscles have been shown to be sensitive to NMBA. Monitoring of these muscles is essential to detect and antagonize residual neuromuscular block. On the contrary, a sparing effect has been demonstrated for the diaphragm and lateral abdominal (AB) wall muscles. These muscles are considered to be resistant to NMBA. NMT monitoring of these muscles is of importance to detect early recovery from neuromuscular block when profound block is requested for surgical purpose. More recently, a recovery profile resembling that of resistant-to-NMBA muscles has been demonstrated for the corrugator supercilia (CSC) muscle. Of interest, the CSC is easy to stimulate and its evoked contraction can be simply observed. We hypothesized that as compared with AP, NMT monitoring of the CSC might reveal information on AB relaxation. We compared visual estimation of NMT of CSC and AP with electromyographic measurements of

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AB during recovery from vecuronium-induced intense neuromuscular block.

Methods

After Ethics Committee’s approval and written informed consent, we selected 10 adult patients (7 men), ASA grade I or II, undergoing elective long-duration peripheral orthopaedic surgery of the lower limb under general anaesthesia. They were between 19 and 56 yr old and had no previous history of abnormal response to NMBA. All patients were free from renal or hepatic disease and were not taking drugs known to interfere with neuromuscular function.

Anaesthetic management

No premedication was given. Anaesthesia was induced with propofol 3.5 mg kg\(^{-1}\) and fentanyl 2 mcg kg\(^{-1}\) and orotracheal intubation performed 2 min later without using NMBA. Anaesthesia was maintained with an inhaled mixture of \(\text{N}_2\text{O}–\text{O}_2–\text{isoflurane}\) (60:40:1.0–1.2%) and supplemented by bolus doses of fentanyl 1 mcg kg\(^{-1}\) every 30 min. Ventilation was controlled to maintain end-tidal carbon dioxide concentration between 30 and 35 mm Hg. During surgery, patients laid supine were covered with a warm air heating blanket. Tympanic temperature was monitored.

Quantitative measurements of neuromuscular block

The method used to measure the evoked AB electrical activity has been described previously.\(^2\) Briefly, single twitches (0.2 ms at 0.1 Hz) were applied to the 10th left intercostal nerve during end expiratory pauses using percutaneous insulated needle electrodes inserted on the posterior axillary line. Satisfactory stimulation of the intercostal nerve caused intense reproducible lateral AB wall motions. The resulting evoked electromyographic (EMG) activity of AB was measured using Ag–AgCl surface electrodes placed on the left anterior axillary line of the thoracoabdominal wall 2 cm apart from the umbilical line. EMG of AB was amplified and recorded with a gated-EMG amplifier using a latency of 2 ms and a window of 20 ms (Viking2, Nicolet Instruments, Trappes, France). Peak-to-peak amplitude of compound action potential activity of anterolateral AB muscles (ABEMG) was calculated.

Clinical protocol

Single twitches (0.2 ms at 0.1 Hz) were applied at the upper branch of the facial nerve through skin Ag–AgCl superficial electrodes and to the ulnar nerve at the wrist to determine supramaximal current intensity. Acceleromyography (Entrans\(^®\), Les Clayes-sous-Bois, France) of CSC and mechanomyography (Myotest; Biometer, Odense, Denmark) of AP were measured and displayed on a personal computer (MacLab16S). After supramaximal stimulation intensities have been defined (8 min stability in responses amplitude) for the three muscles, recording and measurement devices at AP and CSC were removed, the stimulation pattern of both ulnar and facial nerves were switched to train-of-four (TOF) supramaximal stimulation applied every minute, and the patients received an i.v. single bolus (10 s) of vecuronium 0.1 mg kg\(^{-1}\).

Electromyographic measurements

The time course of action of vecuronium on ABEMG was evaluated using the following parameters: onset time, maximum effect, and time to recovery of 25, 50, 75, and 90% of control twitch height.

Visual estimate of NMT

Estimation of neuromuscular function performed by an independent observer blinded to EMG measurements consisted of a simple count of visually detectable TOF responses at CSC and AP.

Data analysis

Values of ABEMG, expressed in percentage of control values, associated with one to four TOF responses at CSC and AP were compared using the Wilcoxon rank sum test (StatView V).

Results

Mean age [range] and mean weight (sd) of the patients were 35 [19–56] yr and 70 (8) kg, respectively. No adverse events or clinically important clinical changes occurred during the study. Mean supramaximal stimulation current intensities were 30, 49 and 27 mA at the 10th intercostal, ulnar, and facial nerves, respectively. The mean time to recovery from vecuronium on AB are presented in Table 1. Mean time to recovery of 1, 2, 3, and 4 TOF responses at CSC and AP are presented in Table 2. The first and second TOF responses at CSC were recovered while AP was still unresponsive to TOF. Reappearance of the third TOF response of CSC coincided with the return of the first TOF response of AP. The first and second TOF

<table>
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<tr>
<th>OT (s)</th>
<th>Emax (%)</th>
<th>TH25 (min)</th>
<th>TH50 (min)</th>
<th>TH75 (min)</th>
<th>TH90 (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>159 (43)</td>
<td>100</td>
<td>42 (8)</td>
<td>48 (8)</td>
<td>56 (7)</td>
<td>62 (7)</td>
</tr>
<tr>
<td>[107–180]</td>
<td>—</td>
<td>[28–54]</td>
<td>[39–63]</td>
<td>[47–69]</td>
<td>[57–76]</td>
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response at CSC reappeared at significantly (P<0.05) lower ABEMG than the same response at AP: 13 (8)% and 26 (9)% vs 56 (10)% and 75 (11)%, respectively (Table 3 and Fig. 1).

Discussion
In the present study, we demonstrated that the first and second TOF responses of CSC reappeared earlier and at significantly lower ABEMG than the same response at AP. We used EMG to measure neuromuscular block of AB, because there is no system available to simply monitor AB muscle relaxation. Moreover, this method has already been used to quantify the degree of lateral AB muscle relaxation.1,2 Mechanomyography of AB muscles has never been described. Of interest, the lateral AB wall is made of a complex of three flat muscles: external oblique, internal oblique, and transverses abdominis supplied by the same nerve roots. Because of their spatial arrangement, bony insertion, and fibre orientation, the lateral AB muscle complex was demonstrated to be particularly efficient at increasing abdominal pressure. An increase in internal bladder pressure resulting from AB lateral muscle twitches might have been an interesting mechanical alternative method to monitor NMT of AB.

Our data support the rationale for our hypothesis. NMT monitoring of CSC reflects AB relaxation better than that of AP. We showed that initial recovery of AB coincided with the reappearance of the first and second response to TOF at CSC (Fig. 1). Moreover, we observed that the clinical duration of action of vecuronium upon AB muscles (time to recovery of 25% activity) almost coincided with return of the second TOF response at CSC (Fig. 1). On the contrary, our data showed that TOF recovery at AP occurred late during the recovery stage of AB muscles, with some patients demonstrating almost 50% abdominal reactivity when the first TOF response at the hand reappeared (Fig. 1).

Our study has some limitations. Firstly, we have used a visual method to quantify neuromuscular block at AP and CSC. Tactile assessment of TOF responses at AP would have been more reliable, but we preferred using the same method of TOF monitoring at both studied muscles. Secondly, by using visual TOF count at AB, we would have been able to extend our visual method to the three studied muscles. But, visual estimation of lateral AB muscle neuromuscular block has never been standardized. Thirdly, we used two different methods for determining supramaximal current intensity of CSC and AP, which might have affected our results. However, we have previously demonstrated that acceleromyography applied to eyebrow and mechanomyography at the hand provided comparable mechanical responses of studied muscles.5

Our findings are of greater interest in clinical practice of anaesthesia, mainly when applied to the control of NMT during abdominal surgery. Although controversies exist in the area of neuromuscular block requirement for abdominal surgery, low potential AB muscle reactivity that we measured when the first TOF response reappeared at CSC is probably sufficient for most urologic, gynaecologic and infra-umbilical types of surgical procedures.6,7 If our results were confirmed, administration of NMBA titrated upon visually detectable TOF responses at CSC might be an interesting strategy to maintain, through repeated bolus injection or continuous infusion of NMBA, a profound neuromuscular block. Allowing the recovery of the first

<table>
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<tr>
<th>TOF</th>
<th>CSC ABEMG (%)</th>
<th>AP ABEMG (%)</th>
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<tr>
<td>T1</td>
<td>17 (6); [9–23]*</td>
<td>56 (10); [40–60]</td>
</tr>
<tr>
<td>T2</td>
<td>27 (7); [19–36]*</td>
<td>75 (11); [59–87]</td>
</tr>
<tr>
<td>T3</td>
<td>52 (7); [41–59]*</td>
<td>88 (11); [68–100]</td>
</tr>
<tr>
<td>T4</td>
<td>74 (8); [71–84]*</td>
<td>94 (9); [79–100]</td>
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Table 3 Electromyographic activity of AB muscles (ABEMG) expressed in percentage of control values, associated with recovery of 1, 2, 3, and 4 visually detectable TOF responses at the CSC and AP muscles after a bolus dose of vecuronium 0.1 mg kg⁻¹. Values are means (sd); [range]. *P<0.05 vs AP

Fig 1 Evoked AB muscle twitch height (sd) measured with EMG (ABEMG) related to reappearance of the first, second, third, and fourth response to TOF stimulation (T1, T2, T3, T4) at the CSC and AP muscles during recovery from vecuronium 0.1 mg kg⁻¹. *P<0.05 vs AP.
response to TOF at CSC warranted low AB muscle reactivity, but reappearance of the second response attested to significant AB muscle recovery (Fig. 1). Then, if deep neuromuscular block is mandatory during upper abdominal surgery, targeting a single response to TOF at CSC could be a rational strategy of myorelaxation. Interestingly, during recovery from vecuronium deep block, the fourth TOF response at CSC reappeared during the early stage of AP recovery (Fig. 1). Our data confirm that recovery at the eyebrow occurs while intense neuromuscular block still affects sensitive hand muscles.

In conclusion, we demonstrated that TOF response count at the CSC, but not at the AP allowed quantification of the degree of AB muscle relaxation during recovery from vecuronium block.

Acknowledgement
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