Influence of serum concentrations of catecholamines and i.v. or volatile anaesthesia on evoked electromyography in the hand

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Summary
We have examined the correlation between serum concentrations of catecholamines and the evoked electromyographic (EEMG) response from the first dorsal interosseous muscle of the hand in 20 patients during minor surgery under propofol or enflurane anaesthesia without neuromuscular blocking drugs. The supinated forearm, with the wrist fully extended, was strapped firmly to an armboard and immobilized with adhesive tape. In the propofol group, the mean EEMG response to the first stimulus in the train-of-four (T1) decreased to 83.0% (95% confidence intervals (CI) 78.7–87.3%) of baseline, while in the enflurane group the mean EEMG T1 response decreased to 84.0% (95% CI 81.6–86.4%) of baseline. The decrease in the EEMG response occurred over 20 min and did not correlate with plasma concentrations of adrenaline or noradrenaline (correlation coefficients all < 0.26). We conclude that the decrease in EEMG response during the first 30 min of anaesthesia occurred during both i.v. and inhalation anaesthesia, and that changes in plasma concentrations of catecholamines did not cause the decrease in the EEMG response.

Key words

Patients and methods
We studied 20 patients, ASA I or II, during minor surgical procedures. The study was approved by the Glasgow West District Ethics Committee and patients gave written informed consent. Premedication comprised i.m. morphine 10 mg and prochlorperazine 12.5 mg.

The patients were anaesthetized in the operating theatre. Routine monitoring comprised ECG, non-invasive arterial pressure and pulse oximetry. The EEMG was monitored with a Relaxograph (Datex, Helsinki) and Blue Sensor P-00-S foam-based disposable electrodes (Medicotest, Ölstykke, Denmark). No skin preparation was used before the electrodes were applied. The ulnar nerve was stimulated at the wrist with supramaximal TOF current pulses of 100-μs duration, repeated every 20 s. The evoked compound action potential was recorded over the belly of the first dorsal interosseous muscle, with the indifferent electrode on the proximal phalanx of the second finger. The ground electrode was placed at the proximal wrist crease. The arm was placed on an armboard at 90° abduction and in full supination. The wrist was extended over a padded 1 inch diameter rod and strapped firmly to the armboard with adhesive tape, leaving the thumb free. A 16-gauge cannula was inserted in an antecubital vein of the opposite arm under local anaesthesia to allow venous blood sampling for measurement of plasma concentrations of catecholamines. The first blood sample was obtained immediately before induction of anaesthesia. Blood samples were placed into prechilled tubes containing lithium-heparin anticoagulant, then stored on ice for a maximum of 2 h before being centrifuged and the plasma fraction deep frozen at −20 °C for later analysis.

Anaesthesia was induced in all patients with propofol 2–2.5 mg kg⁻¹ and a laryngeal mask was inserted. Patients were allocated randomly to one of two groups for maintenance of anaesthesia. One group of 10 patients received a propofol infusion [9] via a dedicated venous cannula in the arm opposite to
EEMG, catecholamines and anaesthesia

Table 1  Mean (95 % confidence intervals) concentrations of catecholamines and mean electromyographic first response to train-of-four stimulation (EEMG T1) for the propofol and enflurane groups

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<th>Baseline</th>
<th>Time (min)</th>
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<tr>
<td>Noradrenaline</td>
<td></td>
<td>(nmol l⁻¹)</td>
<td>Propofol</td>
<td>2.22 (0.59)</td>
<td>1.82 (0.63)</td>
<td>2.06 (0.63)</td>
<td>2.63 (1.01)</td>
<td>2.74 (0.90)</td>
<td>2.72 (1.10)</td>
<td>2.42 (0.88)</td>
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<td>Enflurane</td>
<td>2.44 (0.86)</td>
<td>2.53 (0.79)</td>
<td>2.23 (0.45)</td>
<td>2.45 (0.39)</td>
<td>3.21 (0.69)</td>
<td>3.38 (0.85)</td>
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<td>Adrenaline</td>
<td></td>
<td>(nmol l⁻¹)</td>
<td>Propofol</td>
<td>0.27 (0.07)</td>
<td>0.24 (0.09)</td>
<td>0.27 (0.08)</td>
<td>0.21 (0.08)</td>
<td>0.22 (0.07)</td>
<td>0.28 (0.07)</td>
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<td>Enflurane</td>
<td>0.54 (0.27)</td>
<td>0.44 (0.21)</td>
<td>0.61 (0.30)</td>
<td>0.72 (0.63)</td>
<td>0.73 (0.71)</td>
<td>0.68 (0.50)</td>
<td>0.63 (0.42)</td>
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<td>EEMG T1 (%)</td>
<td></td>
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<td>Propofol</td>
<td>99.5 (0.5)</td>
<td>91.9 (3.3)</td>
<td>87.3 (4.4)</td>
<td>85.5 (4.6)</td>
<td>83.3 (4.2)</td>
<td>83.1 (4.2)</td>
<td>83.0 (4.3)</td>
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<td></td>
<td>Enflurane</td>
<td>99.4 (0.5)</td>
<td>92.6 (2.4)</td>
<td>88.9 (2.5)</td>
<td>87.2 (2.1)</td>
<td>85.8 (2.2)</td>
<td>84.9 (2.8)</td>
<td>84.0 (2.4)</td>
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the sampling cannula. The other group received 1.5% inspired concentration of enflurane. All patients breathed a mixture of 66% nitrous oxide in oxygen via a circle-absorber system with a fresh gas flow of 3 litre min⁻¹; the inspired oxygen and respired carbon dioxide concentrations were monitored continuously. The study started immediately on induction of anaesthesia and within 5 min of attaching the EEMG electrodes. The Relaxograph was calibrated to the 100% transmission reference level immediately after disappearance of the eyelash reflex and the EEMG response was recorded every 20 s thereafter. Additional blood samples were obtained every 5 min for 30 min after induction of anaesthesia; surgery started after the second blood sample, 5 min after induction of anaesthesia.

Frozen plasma samples were thawed and analysed for adrenaline and noradrenaline concentrations by high pressure liquid chromatography (HPLC) with electrochemical detection; the analyst was blinded to the anaesthetic technique. Reference values in the laboratory of the MRC Blood Pressure Unit for supine resting plasma concentrations of adrenaline and noradrenaline were less than 4 nmol l⁻¹ and for noradrenaline less than 0.5 nmol l⁻¹. The detection limit for both catecholamines was 0.1 nmol l⁻¹ and the coefficient of variation for both analyses was 10%. Results were stored and analysed on a microcomputer spreadsheet (Microsoft, Excel v4.0). Results are expressed as mean (95% confidence intervals (CI)).

Results

There were no significant differences between the propofol and enflurane groups in age, sex or body weight of patients, or type of surgery.

In the propofol group, the mean EEMG T1 response decreased from a baseline value of 99.5 (98.8–100.0)% to 83.0 (78.7–87.3)% of the control response during the first 20 min of anaesthesia. Mean plasma concentrations of catecholamines did not change significantly during this time (table 1). One patient had a pronounced increase in plasma adrenaline concentration from a baseline value of 0.23 nmol l⁻¹ to a peak of 3.92 nmol l⁻¹, 20 min after induction, but this was associated with an EEMG response close to the group mean. Plasma noradrenaline concentrations increased above the reference range only in two patients. Catecholamine concentrations did not correlate with the EEMG T1 response, either for individual patients or for the group (correlation coefficients were —0.10 for noradrenaline and 0.0015 for adrenaline).

In the enflurane group, the mean EEMG T1 response decreased from a baseline value of 94.9 (98.9–99.9)% to 84.0 (81.6–86.4)% of the control response over 25–30 min of anaesthesia. Plasma concentrations of catecholamines did not change significantly and did not correlate with the EEMG T1 response (correlation coefficients were —0.05 for noradrenaline and —0.26 for adrenaline).

Although there was a wider dispersion of adrenaline, but not noradrenaline, concentrations in the enflurane group than in the propofol group at each sampling point, this was not associated with a difference in the EEMG response between the two groups. Interestingly, passive supination of the forearm at the end of the study period returned the EEMG response to within 5% of the calibration value in 12 of the 20 patients.

Discussion

The decrease in the baseline EEMG response which occurs during general anaesthesia is currently unexplained, but previous work has shown that it is not caused by the central neural effects of general anaesthesia [7], changes in the impedance of the electrodes used to record the EMG [10] or changes in skin or muscle temperatures [11]. The decrease in the EEMG response also does not seem to occur in awake subjects [7]. Catecholamine receptors are present at the neuromuscular junction and affect neuromuscular function by both pre- and post-junctional mechanisms [12]. Prejunctional α receptors increase release of acetylcholine from the motor nerve terminal, while prejunctional β receptors may increase synthesis and mobilization of acetylcholine. Postjunctional β receptors produce prolonged hyperpolarization of the muscle membrane and clinical depression of neuromuscular transmission when the normal safety margin is decreased. Plasma adrenaline and noradrenaline concentrations increase 3–4 fold during standing from a sitting position [13]. In our study the changes in plasma concentrations of catecholamines were less than this, suggesting that both anaesthetic techniques effectively blocked the sympathetic response to minor surgery. This result is similar to work published previously [14, 15]. The decrease in the EEMG response did not correlate with plasma catecholamine concentrations, which supports the contention that physiological concentrations of cate-
Cholamines probably have no significant effect on neuromuscular transmission in humans unless the margin of safety is decreased [12].

The mean change in the EEMG response was similar in both the enflurane and propofol groups. Propofol has no demonstrable effect on neuromuscular transmission [16], but all volatile anaesthetics are non-specific calcium antagonists and therefore potentially modify neuromuscular function by a variety of mechanisms [17-19]. The reduction in muscle calcium flux by dantrolene, uncoupling excitement and contraction, decreases the force of muscle contraction but has no effect on the EEMG response [20]. Both halothane and isoflurane have been associated with a decrease in the EEMG T1 response to about 80% of baseline in normal patients in the absence of neuromuscular blocking agents [5, 6], although in these reports the force of muscle contraction was also increased simultaneously. However, there was little evidence of a dose-related effect in these studies and the variation in the EEMG response as the patients awakened was wide.

Supination of the forearm restored the EEMG response in 60% of our patients: this response was similar to that seen in a previous study [11]. Pronation and supination of the forearm must alter the effective stimulus current at the ulnar nerve in some patients, as a result of changes in the relative positions of the stimulus electrodes and the ulnar nerve. Unfortunately, the user has to assume that the algorithm in the microprocessor of the Relaxograph for the determination of the supramaximal stimulus current is accurate, as it is not possible to check that the stimulus current is truly supramaximal after it has been determined during calibration. Similarly, there is no facility in the Relaxograph to confirm that the stimulus current remains supramaximal during EEMG monitoring. However, there is a difference in the EEMG response of awake and anesthetized individuals with the Relaxograph, and Meretoja and Brown [4] found that waiting for 20 min after induction of anaesthesia before calibrating the Relaxograph avoids the decrease in the baseline response which occurs if the Relaxograph is calibrated immediately after induction of anaesthesia. We suggest that the decrease in the EEMG response during anaesthesia is the result of some process which changes the supramaximal stimulus threshold, possibly minor pronation or supination of the forearm which alters the relative positions of the stimulus electrodes and the ulnar nerve. This phenomenon occurs with either i.v. or inhalation agents and is not caused by changes in serum catecholamine concentrations during anaesthesia.

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References


