COMPARISON OF VISUAL AND MEASURED TRAIN-OF-FOUR RECOVERY AFTER VECURONIUM-INDUCED NEUROMUSCULAR BLOCKADE USING TWO ANAESTHETIC TECHNIQUES

D. A. O'HARA, R. J. FRAGEN AND C. A. SHANKS

Anaesthetists commonly rely on recovery of the train-of-four response to assess recovery from neuromuscular blockade. Using tubocurarine (in association with halothane anaesthesia), Lee (1975) visually observed the fifth finger of the hand when investigating the correlation between the observed and the measured responses. He found that the fourth, third and second twitches (T4, T3, and T2) of the train-of-four disappeared at 75, 80 and 90% twitch depression, respectively, and reappeared in reverse order. One could, therefore, count the number of twitches seen on recovery from neuromuscular blockade and estimate the intensity of residual blockade.

In a recent study O'Hara, Fragen and Shanks (1986) measured train-of-four recovery (under enflurane anaesthesia) after the administration of vecuronium, atracurium or tubocurarine, the chart recorder showing that T2, T3 and T4 reappeared at approximately 93%, 89% and 86% residual neuromuscular blockade, respectively, for all three drugs. Since the difference between these results and those of Lee (1975) may have been attributable to a difference in the effects of the volatile anaesthetic, we examined the effect of two anaesthetic techniques on the responses observed during vecuronium-induced neuromuscular blockade. In addition, we compared measured isometric contractions at the thumb with visually observed movements in the contralateral hand.

SUMMARY

This study evaluated train-of-four recovery after the administration of vecuronium, comparing measured with visually observed responses. Responses to supramaximal stimuli of the ulnar nerves were measured by a force transducer, and compared with visually observed movements of the contralateral thumb. For the 10 patients anaesthetized with nitrous oxide and enflurane, the second, third and fourth twitches visually reappeared at 84 (±10)%, 76 (±11)%, and 70 (±12)% measured blockade, respectively. For the other 10 patients, anaesthetized with a narcotic-barbiturate technique, the second, third and fourth twitches reappeared at 81 (±8)%, 68 (±9)%, and 59 (±11)%. These results were not different for the two anaesthetic techniques.

PATIENTS AND METHODS

The 13 males and seven non-pregnant females who entered the study (ASA physical status I or II) were scheduled for elective operative procedures requiring neuromuscular blockade. The study was approved by the Institutional Review Board of Northwestern University. The patients were aged from 20 to 60 yr, within 25% of ideal body weight (Bray, 1976), without known renal, hepatic or neuromuscular disease, and had not received drugs known to affect neuromuscular transmission.

The 20 patients were either unpremedicated or received morphine sulphate 0.1 mg kg⁻¹ and atropine 0.4 mg i.m. approximately 1 h before the...
induction of anaesthesia in both groups, with thiopentone 3–5 mg kg⁻¹ i.v.

Patients were randomly assigned, 10 to receive nitrous oxide–enflurane (group 1) and 10 to receive a nitrous oxide–narcotic–barbiturate anaesthetic (group 2). For patients in group 1, anaesthesia was maintained with 1–2% enflurane and 50% nitrous oxide in oxygen; in group 2, anaesthesia with 50% nitrous oxide and oxygen was supplemented with incremental doses of fentanyl 50–100 μg and thiopentone 50–100 mg according to surgical requirements. Since the measurements of recovery were to be made after at least 30 min of anaesthesia, it was felt the enflurane concentration would be at steady-state. End-tidal carbon dioxide tensions were measured continuously (Datex CO₂ monitor, Puritan-Bennett Corp.), and ventilation was adjusted to maintain normocarbia. Nasopharyngeal temperature was monitored continuously.

A Grass S48 stimulator provided train-of-four supramaximal stimuli of 0.2 ms duration to the ulnar nerve at the elbow every 10 s. A Hewlett-Packard 7754B chart recorder was used to monitor the train-of-four response recorded from the thumb via a linear force transducer. Trains-of-four supramaximal stimuli were applied to the contralateral ulnar nerve for visual assessment of the response at the thumb. After a stable train-of-four (four stimuli at 2 Hz at 10-s intervals) baseline was obtained, an intubating dose of vecuronium 0.1 mg kg⁻¹ was administered. The train-of-four response was monitored until the first twitch regained control height.

The time to onset of blockade, time to maximum blockade and time to visually observed recovery of each twitch in the train-of-four were recorded. The percent twitch depression as measured by the force transducer was then determined at the time that each twitch in the train-of-four was discernible on the free hand by the one observer (D.O.) who could not see the recorded response.

Mean values ± standard deviations for the return of each twitch in the train-of-four, for each anaesthetic technique, were calculated. Two-way analysis of variance was used to compare the twitch responses for the two anaesthetic techniques, with repeat measures application within groups, followed by a Bonferroni t test. A P value of less than 0.05 was considered significant (Snedecor and Cochran, 1967).

### Table I. Times, after vecuronium 0.1 mg kg⁻¹, at which the four twitches were visually observed to have returned, and the concomitant intensities of (contralateral) twitch depression (mean (SD))

<table>
<thead>
<tr>
<th>Anaesthetic technique</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrous oxide–narcotic</td>
<td>31 (8)</td>
<td>36 (10)</td>
<td>40 (11)</td>
<td>43 (13)</td>
</tr>
<tr>
<td>Time (min)</td>
<td>92 (4)</td>
<td>81 (8)</td>
<td>68 (9)</td>
<td>59 (11)</td>
</tr>
<tr>
<td>Twitch depression (%)</td>
<td>28 (7)</td>
<td>33 (9)</td>
<td>37 (9)</td>
<td>39 (10)</td>
</tr>
<tr>
<td>Enflurane</td>
<td>94 (3)</td>
<td>84 (10)</td>
<td>76 (11)</td>
<td>70 (12)</td>
</tr>
</tbody>
</table>

## RESULTS

Neither temperature nor end-tidal carbon dioxide concentration changed significantly during the study. The mean ages, heights and weights (± SD) for the two groups were similar: group 1, 38 ± 9 yr, 167 ± 9 cm, and 65 ± 12 kg; group 2, 35 ± 9 yr, 170 ± 14 cm, and 71 ± 10 kg.

The mean times to the visually observed reappearance of each twitch are listed in table I. The mean times (± SD) to onset (first depression of T₁ from control) and maximum blockade under enflurane anaesthesia were 1.3(±0.4) and 3.2(±0.8) min respectively. Under nitrous oxide–narcotic–barbiturate anaesthesia, these were 1.2(±0.3) and 3.0(±0.7) min, respectively. The measured intensity of blockade (control – T₁)/control, at the times of visual recovery of each twitch in the train-of-four for each group are listed in table I. These values were not different for the two anaesthetic techniques.

## DISCUSSION

Times to first onset of blockade and maximum blockade were similar to previously reported data (Nagashima et al., 1981; Buzello and Noldge, 1982; Bencini and Newton, 1984; Hunter, Jones and Utting, 1984), all measured under nitrous oxide–narcotic–barbiturate anaesthesia.

The measured intensities of blockade under enflurane anaesthesia were 94%, 84%, 76% and 70% for the visually observed reappearance of T₁, T₂, T₃ and T₄, respectively; under nitrous oxide–narcotic–barbiturate anaesthesia these were
92%, 81%, 68% and 59% for the visually observed reappearance of T1, T2, T3, and T4, respectively. These results are in general agreement with those of Lee (1975), despite differences in technique—such as his monitoring of the visual response at the fifth finger.

These results show greater recovery of blockade at each component of the train-of-four than that measured (with a force transducer) in our previous study (O'Hara, Fragen and Shanks, 1986), using enflurane along with vecuronium. This would indicate that the visually observed response has a sensitivity different from that of the measured response.

Ham and Redpath (1985) compared the manually felt with the measured train-of-four using halothane and five non-depolarizing neuromuscular blocking drugs: atracurium, pancuronium, tubocurarine, metocurine and gallamine. They found that, during the onset of blockade for tubocurarine, pancuronium and metocurine, the responses were similar to those reported by Lee (1975). For atracurium, the train-of-four disappeared at greater intensities of block; for gallamine at lesser. The train-of-four reappeared at similar intensities of blockade for all of the neuromuscular blocking agents used except gallamine (T2, T3 and T4 returning at 81%, 81% and 67%, respectively). While Ham and Redpath (1985) did not use diazepam, suxamethonium or antagonizing agents in their study, they did use a halothane anaesthetic and used tactile rather than visual observation of the train-of-four. Tactile and visual monitoring of the train-of-four have different sensitivities, tactile being more sensitive than visual (Viby-Mogensen, 1982).

Lee (1975) compared visually observed train-of-four responses of the fifth finger of the same hand in which the force transducer measured thumb contractions. As the fifth finger is less sensitive to neuromuscular blockade than the thumb (Shanks and Harrison, 1973) its train-of-four response might recover at a greater degree of blockade.

By the time that the third twitch in the train-of-four was observed in this study, with either anaesthetic technique, the threshold of adequate surgical relaxation had been reached. DeJong (1966) has indicated that 75% neuromuscular blockade at the hand correlates with adequate relaxation for abdominal surgery. The time between observation of T2 (adequate relaxation) and T3 (inadequate relaxation) in our study was 4 min with either anaesthetic (table I). Therefore, if the administration of additional doses of vecuronium is to be based on observation of the train-of-four, these doses should be given when T2, rather than T4, appears.

In summary, the observed recovery of the train-of-four with vecuronium occurred at a residual blockade of 90-95% for T1, 80-85% for T2, 70-75% for T3 and 60-70% for T4. There was no difference in this pattern of recovery between an enflurane compared with a nitrous oxide–narcotic anaesthetic technique. An average of 12 min elapsed between the return of the first and the fourth responses in the train-of-four, indicating the need for continuous, or at least frequent, monitoring during vecuronium-induced neuromuscular blockade.

REFERENCES


