Relationship of the Train-of-four Fade Ratio to Clinical Signs and Symptoms of Residual Paralysis in Awake Volunteers

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**Background:** Recovery of the train-of-four (TOF) ratio to a value >0.70 is synonymous with adequate return of neuromuscular function, but there is little information available concerning the subjective experience that accompanies residual neuromuscular block wherein the TOF ratio is in the range of 0.70 to 0.90.

**Methods:** Ten American Society of Anesthesiologists' (ASA) physical status 1 volunteers were studied. Control measurements included grip strength in kilograms and ability to perform a 5-s head- and leg-lift. In addition, a standard wooden tongue depressor was placed between each subject's incisor teeth, and he or she was told not to let the investigator remove it. All subjects were easily able to retain the device despite vigorous attempts to dislodge it. Neuromuscular function was monitored with a Datex® (Datex Medical Instrumentation, Inc., Tewksbury, MA) 221 electromyographic (EMG) monitor. TOF stimulation was given every 20 s, and the measured TOF fade ratio was continuously recorded. A 5 mg/kg bolus of mivacurium was then administered, and an infusion at 2 mg·kg⁻¹·min⁻¹ was begun. The infusion was continued until the TOF ratio decreased to <0.70 and was adjusted to keep it in the range of 0.65 to 0.75. Signs and symptoms of weakness were recorded when the TOF ratio had been stable ≥0.03 for at least 10 min during an interval when there were no adjustments in the infusion. All tests noted previously were repeated at this time. The TOF ratio was then allowed to recover to 0.85–0.90. When stable at this level, all tests were repeated, and the infusion was discontinued. TOF measurements were continued until a ratio of 1.0 was attained and until a final set of observations was recorded.

**Results:** The TOF ratio in all subjects was reduced to <0.70. No volunteers required intervention to maintain a patent airway, and the hemoglobin oxygen saturation while breathing air was ≥90% at all times. TOF ratios ≤0.90 were accompanied by diplopia and difficulty in tracking moving objects in all subjects. The ability to strongly oppose the incisor teeth did not return until the TOF ratio (on average) exceeded 0.85. A sustained 5-s head-lift was not achieved until the TOF ratio averaged 0.60 (range, 0.45–0.75). At a TOF ratio of 0.70, grip strength averaged 59% of control (range, 50–75%). With certain exceptions (vision, ability to clench the teeth tightly), there was wide variation in symptomsatology between patients for any given TOF ratio. It is impossible to give reliable TOF break-points at which symptoms and signs will be present or absent.

**Conclusions:** All subjects had significant signs and symptoms of residual block at a TOF ratio of 0.70; none considered themselves remotely "street ready" at this time. The authors believe that satisfactory recovery of neuromuscular function after mivacurium-induced neuromuscular block requires return of the TOF ratio to a value >0.90 and ideally to unity. (Key words: Monitoring: neuromuscular function, train-of-four. Neuromuscular relaxants: mivacurium chloride. Postoperative period: neuromuscular recovery, post-anesthesia care unit, testing.)

IN the mid-1970s, Ali et al. demonstrated that when the train-of-four (TOF) ratio had spontaneously recovered to a value of 0.60, vital capacity, inspiratory force, and peak expiratory flow rate were at clinically acceptable values. Brand et al. confirmed that at a TOF ratio of 0.70, all patients had sustained eye opening, hand grasp, tongue protrusion, and 9 of 10 could maintain head-lift. Based in large part on these studies, many anesthesiologists have come to consider recovery of the train-of-four ratio ≥0.70 as synonymous with adequate return of neuromuscular function. This standard has stood as a reasonable measure of patient safety, however, there is little information available concerning the subjective experience that accompanies residual neuromuscular block wherein the TOF ratio is 0.70–0.90. This issue was of little consequence 20 years ago when few patients were discharged from the hospital within...
hours of surgery. In today's era of ambulatory surgery where rapid return of cognitive function is normal, a new look at standards of neuromuscular recovery seems warranted.

Past attempts to study this association shortly after relaxant administration are difficult to interpret because the relationship between single twitch \( T_1 \) and the TOF ratio measured during recovery does not necessarily apply during onset. The degree of fade at a given amount of initial twitch depression is significantly less during onset than during spontaneous offset of action. After a bolus of pancuronium sufficient to abolish the fourth response to TOF stimulation, peak effects on \( T_1 \) occur in about 6.5 min, but maximum TOF fade takes almost 30 min to develop.

Any attempt to correlate signs and symptoms or residual paresis with the TOF ratio of the adductor pollicis is complicated by an additional factor. Blood flow to different muscle groups varies widely. After an intravenous bolus of a neuromuscular blocking drug, plasma concentrations at a muscle of high perfusion may be decreasing at a time when the peak effect in a muscle of low perfusion may not be evident. We therefore decided to study this issue in unpremedicated awake volunteers who were administered mivacurium by infusion in an attempt to approximate steady state conditions.

Methods and Materials

Ten healthy American Society of Anesthesiologists' (ASA) physical status 1 volunteers (eight male, two female) aged 23–33 years were recruited to participate in this study. All subjects were free from neuromuscular disease and within 15% of ideal body weight. Patients in whom difficulty performing orotracheal intubation may be anticipated were excluded from the protocol. Institutional review was obtained before this project began, and all participants gave informed consent. Subjects were unpremedicated and had fasted for at least 8 hours before drug administration.

Subjects were placed in a modified supine position with the head raised slightly and the knees flexed 15–20°. Patients breathed room air. A pulse oximeter continuously recorded hemoglobin oxygen saturation \( \text{SpO}_2 \). The neuromuscular function of the adductor pollicis or first interosseous muscle was monitored with a Datex® 221 NMT monitor using surface electrodes. Once an adequate evoked response (>10 mV peak to peak) and a stable baseline were achieved, further increases in evoked amplitude were not sought. Delivered current ranged from 45 to 60 mA with a pulse width of 100 ms. We intentionally did not attempt to reach supramaximal levels of stimulation in our subjects. All our volunteers were unpremedicated; TOFs were repeated every 20 s, and the shortest period of observation approached 90 min. Visual Analogue Scale (VAS) pain scores associated with supramaximal TOF stimulation average 5.0 or more. We did not believe it was practical to ask our subjects to submit to such a protocol. Brull et al. and Silverman et al. have demonstrated that provided all four responses to TOF stimulation can be elicited and that the pulse delivered exceeds the initial threshold to stimulation (ITS) by at least 10 mA, the TOF ratio is constant over a wide range of stimulating currents. The test hand was immobilized, and approximately 200–300 g of resting tension was applied to the thumb.

Before the administration of mivacurium, each subject was asked to carry out a variety of tasks, which served as control values. Hand-grip strength in kilograms (average of three attempts) was measured with a Jaymar® (J. A. Preston Corporation, Jackson, MI) dynamometer. Each subject also was asked to perform a 5-s head-lift and a 5-s leg-lift. In addition, a standard wooden tongue depressor was placed between each subject's incisor teeth, and he or she was told not to let the investigator pull it out of his or her mouth. All subjects were easily able to retain the device despite rather vigorous attempts to dislodge it.

Once the subject had become acclimated to the nerve stimulator, a single bolus of mivacurium, 5 mg/kg, was administered, and an infusion at 2 mg·kg\(^{-1}·\text{min}^{-1}\) was begun. The mivacurium infusion was continued until the TOF ratio decreased to <0.70 and was adjusted as necessary to keep it 0.65–0.75. Signs and symptoms of weakness were recorded when the TOF ratio had been stable ± 0.03 for at least 10 min during an interval when there were no adjustments in the infusion rate. All tests noted previously were repeated at this time. In addition, subjects were asked to sip water from a cup via a straw and to note if any difficulty with this task was encountered. They were also encouraged to verbalize any thoughts or sensations as they occurred and to comment on their ability to talk and smile and on their general feeling of well-being. The infusion rate was then decreased, and the TOF ratio was allowed to recover to 0.85–0.90. Once the TOF ratio was stable at this level, all tests were repeated, and the infusion was dis-
CLINICAL SIGNS AND SYMPTOMS OF RESIDUAL PARALYSIS

Table 1. Clinical Signs of Residual Weakness vs. the Train-of-four Fade Ratio at the Adductor Pollicis Muscle

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Lowest TOF Attained</th>
<th>Head-lift</th>
<th>Leg-lift</th>
<th>Retain Tongue Depressor</th>
<th>Highest TOF Ratio at which Test Was Failed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.58</td>
<td>0.60</td>
<td>0.60</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>0.52</td>
<td>0.56</td>
<td>0.60</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>0.58</td>
<td>0.60</td>
<td>0.60</td>
<td>0.91</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>0.42</td>
<td>0.48</td>
<td>0.50</td>
<td>0.68</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>0.52</td>
<td>0.55</td>
<td>0.60</td>
<td>0.91</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>0.44</td>
<td>0.52</td>
<td>0.52</td>
<td>0.88</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>0.68</td>
<td>0.75</td>
<td>0.68</td>
<td>0.95</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>0.50</td>
<td>0.68</td>
<td>0.63</td>
<td>0.88</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>0.60</td>
<td>0.75</td>
<td>0.66</td>
<td>0.90</td>
<td>+</td>
</tr>
<tr>
<td>10</td>
<td>0.52</td>
<td>0.67</td>
<td>0.55</td>
<td>0.80</td>
<td>+</td>
</tr>
</tbody>
</table>

Mean   0.54    0.62   0.59   0.86   0.79
SD     0.08    0.09   0.05   0.08   0.14
Range  (0.42–0.68) (0.48–0.75) (0.50–0.65) (0.68–0.95) (0.50–0.90)

* Test not performed.
† Not determined or ability never lost. The ability to perform head- or leg-lift was not always tested at the point when the TOF ratio was at its nadir, hence these data are incomplete.

continued. TOF measurements were continued until a TOF ratio of 1.0 was attained and until a final set of observations was recorded. At this point, obvious signs of weakness usually were absent, but it was common for subjects to note that in some manner they still felt a little “off-center.” All subjects were told to report to the investigators the time interval (if any) between discharge from the experiment and the moment when they felt back “normal.”

Grip strength at TOF ratios of 0.70, 0.90, and control were compared for differences using a Kruskal-Wallis one-way analysis of variance (ANOVA; P < 0.05 = significant).

Results

The TOF ratio was reduced to a level <0.70 (as measured at the adductor pollicis muscle) in all subjects. During the initial onset of neuromuscular block, it was difficult to titrate the TOF ratio to exactly the range desired, and there usually was some initial “overshoot” to levels less than the target ratio (0.65–0.70; table 1). Signs and symptoms referenced to this range of TOF ratios occurred after a stable level of blockade at that level had been achieved. Twitch height (T1, in each TOF) never decreased by more than 10% in any subject and was usually maintained at control levels despite decreases in the TOF ratio. No volunteer required inter-

vention by the investigators to maintain a patent airway, and the SpO2 was maintained at ≥96% in all subjects at all times. Infusion rates required for maintenance of a TOF of 0.70 ranged from 1.15 to 3.0 mg·kg⁻¹·min⁻¹ (mean, 1.8). Infusion times averaged 100 ± 16.5 (SD) min (range, 80–140).

Table 2. Grip Strength vs. the Train-of-four Fade Ratio at the Adductor Pollicis Muscle

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Grip Strength (% control at TOF = 0.70)</th>
<th>Grip Strength (% control at TOF = 0.90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>77</td>
<td>87</td>
</tr>
<tr>
<td>2</td>
<td>49</td>
<td>81</td>
</tr>
<tr>
<td>3</td>
<td>59</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>64</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>48</td>
<td>72</td>
</tr>
<tr>
<td>6</td>
<td>49</td>
<td>86</td>
</tr>
<tr>
<td>7</td>
<td>66</td>
<td>80</td>
</tr>
<tr>
<td>8</td>
<td>65</td>
<td>92</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>85</td>
</tr>
<tr>
<td>10</td>
<td>43</td>
<td>105</td>
</tr>
</tbody>
</table>

Mean 57.0† 83.3†
SD 10.7 10.3
Range (43–77) (70–105)

* These TOF ratios represent target values. Individual ratios may vary by ±0.03.
† P < 0.01. Grip strength at TOF = 0.90 also is different from control with P < 0.01.

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All of the subjects rapidly acclimated to peripheral nerve stimulation at pulses averaging 5–6 μC (10 mA x 0.10 ms = 1 μC); no one complained of pain or showed obvious distress from this aspect of the protocol.

**Observations during Onset of Train-of-four Fade**

Train-of-four fade was slow to develop. It took on average 25 min (range, 15–35 min) for the TOF ratio to decrease to <0.90 and 30 min (range, 20–50 min) to decrease to ≤0.70. Pronounced symptoms of neuromuscular weakness appeared shortly after the initial dose of relaxant. For example, 16 min after the infusion had begun (cumulative dosage of mivacurium, 0.04 mg/kg) subject 6 was unable to perform a head-lift, could not approximate his incisor teeth, and was having difficulty swallowing. His TOF ratio was 1.00. Therefore, TOF ratios measured at the adductor pollicis during the onset of block may markedly underestimate the extent of weakness in the muscles of the neck and jaw.

**Observations during Steady State Train-of-four Depression**

**Vision.** Train-of-four ratios of 0.90 were accompanied by significant visual disturbances in all subjects. Below this level of recovery, every subject complained of diplopia and difficulty in tracking moving objects, and these symptoms often persisted despite full return of the TOF ratio. Seven subjects believe that their vision was abnormal at a time when the TOF ratio had recovered to 1.00. One subject stated “I don’t have double vision anymore, but things just don’t look right. It’s sort of like the sensation of putting on a new pair of glasses that you are not used to.” These seven subjects reported that it took between 45 and 90 min after return of the TOF ratio to a value of 1.00 before they believed that vision had completely recovered to normal.

**Masseter Strength.** Before mivacurium administration, all subjects could easily prevent a wooden tongue depressor clenched between their incisor teeth from being pulled out by even a vigorous effort. This ability did not return on average until the TOF ratio exceeded 0.86 (table 1), although one subject was able to prevent extraction of the tongue depressor at a TOF of 0.68. In the majority of subjects, however, at the latter value only weak opposition to removal of the tongue depressor could be mounted. Although resistance increased from this level on, the point at which the tongue depressor could not be dislodged was unambiguous.

**Head-lift and Leg-lift.** Once the TOF ratio achieved a value ≥0.60, sustained head- and leg-lift usually were present (table 1). Three subjects were able to accomplish head-lift at TOF ratios of 0.48 to 0.55, and all subjects were able to achieve a 5-s head- and leg-lift at a TOF ration of 0.75.

**Grip Strength.** At a TOF ratio of 0.70, grip strength was decreased in all subjects, but there was considerable individual variation (table 2). At a TOF ratio of 0.70, grip strength averaged 57% of the control, with a range of 43–77%. This strength increased to 83% of the control (range, 70–105%) at a TOF ratio of 0.90. Both of these values were different from each other and from control with $P < 0.01$.

**Miscellaneous Observations.** With certain notable exceptions (vision, ability to clench the teeth tightly), there was variation in symptoms between subjects for any given TOF ratio. In some subjects, head-lift and leg-lift returned simultaneously, in others, the leg-lift was never lost. In addition, subjects often reported that symptoms may wax and wane at a time when the TOF ratio was stable. It is impossible to give definitive TOF break-points at which most symptoms and signs will be present or absent.

At TOF ratios <0.75, all subjects were uncomfortable. Most reported that speaking required great effort and that swallowing was becoming difficult. Most found it impossible to sip water through a straw because they could not maintain a tight seal with their lips. Finally, all subjects at this level of block had the same "flat" expression. We believe that this was a reflection of significant involvement of the facial muscles.

**Discussion**

Our results support the finding of other investigators that TOF fade is slow to develop. Observations made shortly after the administration of small pretreating or priming doses of nondepolarizing relaxants, which attempt to correlate signs and symptoms of partial paralysis with recorded TOF ratios, are unlikely to be applicable to the clinical situation that occurs during spontaneous or anticholinesterase-induced recovery of neuromuscular function. Thus, very little of the currently available information on the subjective effects or residual block experienced at TOF ratios in the range of 0.70–1.00 should be accepted uncritically. Priming doses of nondepolarizing relaxants have been cited as producing easily detectable detrimental effects of the
mechanisms of swallowing as measured electromyo-
graphically (EMG) 3–6 min after drug administration. For
example, Isono et al. found that 0.02 mg/kg of
pancuronium resulted in ptosis, blurred vision, a 66%
depression in the EMG activity of the suprahyoid mus-
cles, and difficulty in swallowing in five of eight subjects
studied. At this time, grip strength was minimally af-
fected, and the TOF ratio measured at the adductor pollicis was >0.80. For reasons outlined previously, we
do not believe that the magnitude of TOF fade measured
in peripheral muscles at this time is relevant to the
clinical circumstances during return of neuromuscular
function at the end of anesthesia.

It is now well established that return of the TOF ratio
to an excess of 0.70 represents almost complete return of
mechanical respiratory reserve and the ability to satis-
factorily maintain a patent airway. Although statistically
significant decreases in the forced vital capacity,
forced expiratory volume in 1 s (FEV1), and peak expira-
tory flow rate can be demonstrated at this level of recov-
ery, these changes are probably of no clinical impor-
tance. Ali’s pioneering work on this subject was done
in a era in which early patient discharge from the hospi-
tal was uncommon. In addition, rapid recovery of cogni-
tive function was less easily accomplished 20 yr ago.
Diethyl ether and methoxyflurane were still widely used
anesthetic agents, and halothane was considered a drug of
low blood solubility. Thus, the issue of a patient’s per-
ceptions of residual weakness immediately after sur-
ery was not a pressing one. Today, in an environment
wherein patients may be discharged from the hospital
within 2–3 h of leaving the operating room, the prob-
lem of lingering paresis takes on greater relevance.

In addition, there has been a slow accumulation of
information suggesting that nondepolarizing neuromus-
cular blocking drugs may have undesirable effects at
TOF ratios as high as 0.90. There is convincing evidence
that even partial neuromuscular block (TOF, 0.70) im-
pairs the ventilatory response to hypoxia, suggesting
an effect of nondepolarizing relaxants on carotid body
hypoxic chemosensitivity.

Eriksson et al. also demonstrated that TOF ratios
<0.90 are associated with functional impairment of the
muscles of the pharynx and upper esophagus and there-
fore a potentially decreased ability to protect the airway
against regurgitation and aspiration.

It is widely accepted that the ability to sustain a 5-s
head-lift is associated with sufficient strength in other-
wise healthy subjects to protect the airway against ob-
struction and aspiration of oral contents. There is less
agreement on the correlation between a sustained head-
lift and the TOF fade ratio at the adductor pollicis muscle. El Mikatti et al. found that seven of seven subjects
were able to sustain a head-lift at a TOF ratio of 0.50
measured on EMG. Dupuis et al. reported similar re-
results (six of seven) using mechanomyography, but they
found that when EMG monitoring was used that the
TOF ratio had to attain a value of 0.70 before all subjects
had a sustained head-lift. Sharpe et al. using EMG
found that head-lift was uniformly maintained at a TOF
ratio ≥0.60. However, Engbæk et al. (also using EMG)
concluded that the TOF ratio had to recover to 0.80
before all patients could sustain head-lift for 5 s, and
head-lift could not be sustained for any patient at a TOF
ratio of 0.50. Our observations are in general agreement
with those of Engbæk and suggest that the ability to
sustain a head-lift usually first occurs at a TOF ratio of
0.45–0.75 and that finer distinctions are probably not
possible. One of our subjects, an extremely fit man aged
23 years could not maintain a 5-s head-lift until the TOF
ratio was 0.75, and a 10-s head-lift required a TOF ratio
of 0.85. This same subject had no difficulty maintaining
a 10-s head-lift at a TOF ratio of 0.68. The ability to per-
form a 5-s head-lift is not necessarily a precise end-point.
Several of the subjects when finally able to perform
a 5-s head-lift were obviously distressed by the effort
required and clearly could not have sustained a 10-s
head-lift.

In a 1989 editorial, Miller suggested that there was a
need for more sensitive indices of the adequacy of revers-
al of neuromuscular blockade. An unexpected result of
our investigation was the identification of a simple
clinical test of neuromuscular function that is more sen-
tive than the 5-s head-lift. None of our subjects could
perform the “tongue depressor test” adequately at a
TOF ratio <0.70, and the value at which it was usually
accomplished was ≥0.85. We believe the tongue de-
pressor test may also prove more useful than the head-
lift test in situations where active patient cooperation
is not feasible. For example, during emergence from
anesthesia, inability to manually force open a patient’s
jaw to remove a bite block or oral airway probably
indicates a TOF ratio well in excess of that which is
required to perform a simple head-lift. The question of
masseter sensitivity to nondepolarizing neuromuscular
blocking drugs is an area of some interest. We are aware
of only one pertinent investigation in adults. Smith et
al. found the masseter to be only slightly more sensi-
tive than the adductor pollicis to pancuronium with
ED90 values of 0.38 and 0.43 mg/kg, respectively. These
authors hypothesized that return of adductor pollicis function may not imply complete masseter muscle recovery, however, the relative durations of action in these two muscles was not actually measured.

Although several of our subjects complained of difficulty in swallowing at TOF ratios in the range of 0.45 to 0.60, this was not a prominent symptom once the TOF ratio exceeded 0.75. Our subjects' subjective reports do not provide support for the observations of Eriksson et al. We also were surprised by the prominence of symptoms relating to paralysis of the muscles of facial expression. After nondepolarizing-induced block, return of neuromuscular function in the muscles of the face has been uniformly reported to occur earlier than in the adductor pollicis. Although we find it difficult to reconcile the reports of our volunteers with the objective measurements of orbicularis oculi function reported by others, they were nonetheless real to our subjects. All volunteers reported that their faces felt "numb" at a time when head-lift was easily performed.

We recognize that a difficulty with the present investigation is our inability to quantitate the subjective reports of our subjects. Nevertheless, our results are not compatible with the popular belief that a TOF ratio of 0.70 (as measured at the adductor pollicis muscle) signifies satisfactory return of neuromuscular function. At a TOF ratio of this magnitude, none of our volunteers found airway maintenance a problem. All agreed, however, that they were not "street ready." Although symptoms varied from subject to subject, TOFs in the range of 0.70-0.75 were associated with all of the following symptoms: diplopia and various visual disturbances, decreased grip strength, inability to maintain incisor teeth apposition, inability to sit up without assistance, severe facial weakness including an inability to make an airtight seal around a drinking straw with the lips, speaking described as a major effort, and overall weakness and tiredness. All of the aforementioned symptoms may be present despite the ability to perform a 5-s head-lift. Once the TOF ratio reached a value of 0.85-0.90, the major remaining symptoms were visual problems and a generalized fatigue. At a TOF ratio of 0.90-1.00, diplopia usually started to abate, although a TOF ratio of 1.00 did not guarantee full return of function of the extraocular muscles. Several subjects reported that diplopia persisted for periods in excess of 1 h after termination of the mivacurium infusion.

Another potential criticism of our methodology is that not all investigators are convinced that stimulating currents of 10 mA produce reliable measurements of the TOF ratio. Helbo-Hansen et al. suggested that delivered currents (at 0.2 ms) have to exceed ITS by at least 25 mA before TOF accuracy (the difference between TOF ratios at lesser currents and the TOF ratio at 58 mA) can be assured. They concluded that the accuracy of TOF monitoring is unacceptable at currents < ITS + 25 mA. Because ITS in their series averaged 20 mA, they in effect recommend that currents of < 45 mA should not be used. A pulse of 45 mA with a duration of 0.20 ms represents a delivered charge of 9.0 μC. This raises a major dilemma. The maximum output of the Datex NMT monitor is only 7.0 μC! If the conclusions of Helbo-Hansen et al. are accepted, then the entire world database of information collected with the Datex unit would have to be discarded. We do not believe that this is reasonable.

Finally, can our results using mivacurium as the test drug be extrapolated to other relaxants? There are remarkably few data to suggest that for any given level of T1 recovery that real differences in TOF fade actually exist between commonly used nondepolarizing blockers. The opposite is true. McCoy et al. in a study of atracurium, vecuronium, rocuronium, and mivacurium found that at 90% recovery of T1 that the average TOF ratio for all four agents was 0.59, with a range of 0.53-0.61 (n = 10 per group. NS). Hence, we believe that our data are likely to be applicable to relaxants other than mivacurium.

We conclude that any definition of "satisfactory" recovery of neuromuscular function after the administration of a nondepolarizing neuromuscular blocking drug should be context-sensitive. In a subject recovering from intraabdominal surgery and receiving opioids in amounts sufficient to control postoperative pain, diplopia or diminished grip strength is unlikely to be of major concern. Visual disturbances and facial weakness may be disquieting to the patient who has otherwise fully recovered from the effects of anesthesia and is attempting to ambulate or sip liquids through a straw. Thus we believe that "adequate" recovery of neuromuscular function in the outpatient setting requires return of the TOF ratio to a value ≥ 0.90 and ideally to unity.

References


Anesthesiology, V 86, No 4, Apr 1997


22. Miller RD. How should residual neuromuscular blockade be detected? Anaesthesiology 1989; 70:579-80


26. Sharpe MD, Moote CA, Lam AM, Manninen PH. Comparison of integrated evoked EMG between the hypothenar and facial muscle groups following atracurium and vecuronium administration. Can J Anaesth 1991; 38:318-23


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