**Criteria of Adequate Clinical Recovery from Neuromuscular Block**

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This study was undertaken to compare the sensitivities of the train-of-four response (2 Hz for 2 s), the single twitch (0.15 Hz), and the tetanic response (50 Hz for 5 s) as indices of residual nondepolarizing block. Spontaneous or induced recovery of evoked thumb adduction in response to ulnar nerve stimulation was studied. One hundred and seven adult surgical patients were divided according to the relaxant used, into six groups. We found that when the single twitch recovered to control height, the train-of-four ratio was well below 1.0. This ratio was significantly lower during spontaneous recovery than following neostigmine antagonism of the block (P < 0.01). The tetanic response was fully sustained when the train-of-four ratio was above 0.7. When the ratio was less than 0.7, variable degrees of fade of tetanus were evident. Analysis of variance indicated similar train-of-four ratios among the six groups at complete recovery of the single twitch irrespective of the relaxant technique used (P < 0.1). It is concluded that a train-of-four ratio of 0.7 or higher reliably indicates the recovery of the single twitch to control height and a sustained response to tetanic stimulation at 50 Hz for 5 s. The clinical significance of this study is as follows: the train-of-four response provides the same indication of clinical recovery from nondepolarizing block as obtained from tetanic stimulation at a physiological frequency; and reliance on the recovery of the single twitch to control height as a criterion of spontaneous return to normal clinical neuromuscular function may be misleading. (Key words: An-tagonists, neuromuscular relaxants: neostigmine. Measurement techniques: neuromuscular blockade. Monitoring: stimulator, nerve. Neuromuscular relaxants: d-tubocurarine; metocurine; pancuronium. Neuromuscular transmission.)

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I HERElN revisit our article¹ published two decades ago in *Anesthesiology*. The revisitation in this journal fulfills our dream of witnessing an idea become an established landmark for monitoring the response to an important class of drugs (muscle relaxants) in our day-to-day practice of anesthesia and in assessing criteria of adequate clinical recovery that ensure patient safety in the perioperative period (see Web Enhancement for photograph on the *Anesthesiology* Web site at http://www.anesthesiology.org).

Prior to 1970, neuromuscular blocks in humans were sporadically measured as either the response to single, repeated, motor nerve stimuli or to brief tetanic stimulation.²,³ Neither method was satisfactory. On the one hand, the return of the single twitch to a control response does not indicate complete recovery, assuming a control response has even been established. On the other hand, tetanic stimulation is painful in conscious patients or those recovering from anesthesia. Moreover, frequencies higher than 50 Hz are nonphysiologic.⁴ To improve patient monitoring, Utting, Gray, and I⁵-⁷ examined the evoked muscle response to various frequencies of single, repeated neural stimulation at (0.1–10 Hz) and to a train-of-four (TOF) ratio at 2 Hz for 2 s. The latter was repeated once every 10 s. As we reported in three consecutive articles, we confirmed that the TOF ratio (the height of the fourth evoked response as a fraction of the first response in the same train) is an objective index that does not need a control response to indicate recovery from a nondepolarizing neuromuscular block. We found that, at a TOF ratio of...
tetanic stimulation is a more sensitive index of recovery when the response to the single twitch at 0.15 Hz re-
together with fade of tetanic tension at 50 Hz at the times lar blocking drugs. We, therefore, compared the TOF 
70 Hz was not sustained in the absence of neuromuscu-
tary in an animal model, which does not apply to the 
clinical setting, and concluded that the TOF ratio is 
slightly more sensitive than the single twitch at 0.1 Hz 
and far less sensitive than a 5.0-s 100-Hz tetanus.

However, we were convinced that the TOF ratio is 
more sensitive than the single twitch at 0.15 Hz and at 
least as sensitive as the response to a 5.0-s 50-Hz tetanus. In addition to the fact that the latter frequency is more 
physiologic than 100-Hz tetanus, Stanec et al. 10 showed that 5.0-s tetanic stimulation at a frequency higher than 
70 Hz was not sustained in the absence of neuromuscu-
lar blocking drugs. We, therefore, compared the TOF 
ratio with fade of tetanic tension at 50 Hz at the times when the response to the single twitch at 0.15 Hz re-
covered to the control height. 1 In this revised article, we reported that, irrespective of the muscle relaxant 
used, patients who were allowed to recover spontane-
ously until the single twitch reached control height showed significantly greater fade of the TOF response 
(TOF ratio = 44 ± 5%) than did patients following reversal with neostigmine (TOF ratio = 68 ± 4%, P < 
0.01). In 18 of 28 patients where tetanic response fol-
lowed TOF, tetanus was fully sustained at a TOF ratio of 
73 ± 2%, P < 0.01. In the remaining 10 patients, both 
TOF and tetanic responses showed variable degrees of fade. The TOF ratio was 64 ± 3%, while tetanic response 
ratio was 76 ± 4%, P < 0.05.

Engback et al. 11 advocated another pattern of nerve stimulation that used two short bursts of three stimuli at 
a frequency of 50 Hz separated by 750 ms. This pattern was described as “double burst stimulation.” Engback et 
al. claimed that they could manually discern a degree of fade to double burst stimulation when the TOF response appears to show no fade, but they were uncertain about 
the degree of manual or visual fade of the tetanic re-
sponse at 50 Hz for 5 s. My personal experience was that 
itis was very hard to discern the difference between the 
two bursts because, with the arrival of the first burst, the patient moves the hand vigorously enough to make 
comparison with the second burst of stimulation very dif-
cult.

The question always arises, which TOF ratio would correlate with adequate clinical recovery? A ratio greater 
than 0.75 was found to correlate with signs of adequate 
recovery from nitrous oxide–oxygen–opioid balanced 
anesthesia as well as with recovery during the perioper-
ative period. 12,13 Other clinical investigators suggested that a TOF ratio of at least 0.9 would ensure that the 
patient could be discharged safely from the ambulatory 
care facility. 14

It should be emphasized that, irrespective of the 
method used in assessing adequacy of clinical recovery, 
one has to consider as many criteria as possible to ascer-
tain the return of muscle strength to a level compatible 
with adequate pulmonary ventilation and protection of 
the upper airway. These include the responses to tetanic 
stimulation, TOF, double burst stimulation, and an in-
spiratory force of at least 30–40 cm H 2 0 negative pres-
sure. Further criteria include the ability of the responsive 
patient to sustain as many voluntary activities as possible: head lifting, leg raising, hand gripping, eye opening, 
tongue protrusion, adequate swallowing, and, last but 
not least, adequate coughing.

In conclusion, John Norman, in a 1998 commentary 15 
on our first article, 5 stated that the introduction of TOF 
monitoring was a noteworthy achievement. After its 
introduction, neuromuscular block was monitored more 
often and better assessed.

References

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