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## Tactile and Visual Evaluation of the Response to Train-of-four Nerve Stimulation

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The evoked response to nerve stimulation may be evaluated in four different ways, *i.e.*, electromyographically, mechanically, visually, or manually.<sup>1</sup> Ideally the response should be evaluated mechanically or electromyographically. Most often, however, the response is evaluated solely by eye or touch. Thus, intense neuromuscular blockade can be evaluated by counting the posttetanic twitches, PTC,<sup>2</sup> likewise, a moderate degree of blockade by counting the number of responses to train-of-four (TOF) stimulation.<sup>3,4</sup> During recovery from neuromuscular blockade, when all four responses to TOF stimulation are present, an estimation of the magnitude of the fourth response in relation to that of the first is normally attempted, giving the TOF ratio and thus the degree of residual neuromuscular blockade. However, Savarese and Ali<sup>5</sup> have shown that, on a visual basis, it is often difficult to quantitate the TOF ratio. No one has investigated whether it is possible to judge a TOF ratio manually with sufficient certainty to exclude residual curarization.

The present study was therefore designed to evaluate the accuracy with which anesthetists are able to judge a given TOF ratio without access to recording equipment.

### MATERIALS AND METHODS

Subjects of the study were 168 adult patients ASA class 1 and 2 undergoing elective gynecologic or gastroenter-

ologic surgery. No patient had neuromuscular disease nor received any drug that might alter neuromuscular function. Our study plan was approved by the Ethics Committee at our hospital, but informed consent was not obtained, as the anesthetic and monitoring procedures were those normally used.

One hour after administration of 0.2 mg · kg<sup>-1</sup> diazepam orally, anesthesia was induced with 3–5 mg · kg<sup>-1</sup> iv thiopental and maintained with inhalation of nitrous oxide 67% and either halothane 0.75–1.50% inspired concentration or fentanyl and droperidol iv as required. Ventilation was controlled. Tracheal intubation was carried out following iv administration of succinylcholine 1.0–1.5 mg · kg<sup>-1</sup>. For further paralysis, pancuronium was used.

Following induction of anesthesia, the ulnar nerve at both arms was stimulated at the wrist through cutaneous electrodes connected to a Myotest<sup>®</sup> nerve stimulator<sup>5</sup> with the use of TOF nerve stimulation. On one arm (the control arm) the adduction force of the resultant thumb twitch was measured by the transducer and recorded on a polygraph. On the other arm (the test arm) the response to nerve stimulation was evaluated manually and/or visually. The observers did not know the actual TOF ratio as measured mechanically.

The study consists of three parts.

*Part 1: Evaluation of TOF by Inexperienced Observers.* The aim of the first part of the study was to evaluate how accurately inexperienced observers were able to evaluate fade in the TOF response visually and manually.

Twenty-nine anesthetists who had no special interest or routine in neuromuscular monitoring but who had been taught the rational use of a nerve stimulator evaluated different TOF responses (the inexperienced observers, Group I). The response to TOF stimulation was estimated visually and manually in random order. For the manual estimation, the observer rested his or her fingertips on the abducted thumb of the patient so as to produce a preload. The observer simply had to decide whether or not there was fade in the TOF response.

Thirty patients were included in this part of the study, and the observers estimated the response manually and visually 95 times. A maximum of six different TOF ratios were evaluated in each patient.

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Key words: Monitoring: stimulator, nerve; train-of-four. Neuromuscular relaxants: pancuronium. Neuromuscular transmission: stimulator, nerve.

§ Savarese JJ, Ali HH: Accurate prediction of individual Metocurine dosage by clinical observation of "Threshold fade" on train-of-four stimulation. Abstract from meeting of the American Society of Anesthesiologists, New Orleans, 1977.

TABLE 1. Manual Evaluation of Fade in TOF Response by Moderately Experienced Observers (Group 2) and Very Experienced Observers (Group 3)

True TOF Ratio	Group 2		Group 3	
	Fade/Total	%	Fade/Total	%
<0.30	13/17*	77	32/32	100
0.31-0.40	—	—	12/12	100
0.41-0.50	9/16	56	14/21	67
0.51-0.60	—	—	3/19	16
0.61-0.70	6/17	35	9/40	23
>0.70	1/30	3	8/58	14

\* Figures indicate number of cases in which fade was felt in relation to total number of observations within each interval of true TOF ratios (as measured mechanically).

*Part 2: Evaluation of TOF Ratio by Experienced Observers.* The purpose of this part of the investigation, which was carried out 2 years later, was to find out how accurately anesthesiologists who were more experienced in the use of nerve stimulators could estimate the TOF ratio without use of transducers and recording equipment. The anesthesiologists were divided into two groups.

Group 2 (moderately experienced observers) included 24 anesthesiologists, who had no special interest in neuromuscular monitoring but all of whom had at least 2 years of experience in the use of nerve stimulators. Seven anesthesiologists also had participated in the first part of the study.

Group 3 consisted of two observers, who had not only special interest but also long experience in neuromuscular monitoring. The following questions were asked: 1) Do you feel fade in the TOF response? 2) If so, what would you estimate the TOF ratio to be?

The anesthesiologists from Group 2 evaluated the response 80 times in 29 patients. The corresponding figures in Group 3 were 182 and 51, respectively. In both groups the response was evaluated manually only. As in part 1, a maximum of six different TOF ratios were judged in each patient.

*Part 3: Evaluation of "Threshold Fade" in the TOF Response.* The aim of this part of the study was to evaluate at which TOF ratio very experienced observers were able to see or feel fade in the TOF response during onset and recovery from nondepolarizing neuromuscular blockade.

Three observers participated. They were allowed to see and feel the response to TOF stimulation before injection of the neuromuscular blocking agent. After this, repetitive small doses of pancuronium were injected and the observers indicated when they first felt or saw fade in the response. Manual evaluation of the response was carried out either with the hand resting in the patient's hand or by feeling the response at the thumb as previously described. During recovery from neuromuscular block-

ade, the observers indicated when they could not see or feel fade any more.

The TOF response was evaluated a total of 116 times in 58 patients.

The chi-square test was applied for statistical comparison.  $P < 0.05$  was considered significant.

## RESULTS

*Part 1.* In Group 1 (the inexperienced observers) almost everyone was able to feel fade when the TOF ratio was 0.30 or less. However, at a TOF ratio of 0.41-0.50 only 37% (11 out of 30) of the observers noticed fade visually and 57% (17 out of 30) manually. When the ratio was between 0.61 and 0.70, the corresponding figures were 8% and 16% (two and four out of 25, respectively). Although these figures seem to indicate that manual evaluation is slightly superior to visual evaluation, the difference is not statistically significant.

*Part 2.* Table 1 shows the number of cases in which fade was felt at different TOF ratios by the moderately experienced observers (Group 2) and the very experienced observers (Group 3). There was no significant difference between the results of Group 1 (inexperienced observers) and group 2 (moderately experienced observers), nor was any significant difference found between Groups 2 and 3. However, the results obtained in Group 3 were significantly better than those of Group 1. As appears from the table, the very experienced observers always felt fade when TOF ratio was below 0.40. When the ratio was 0.41-0.50 and 0.51-0.70, fade was felt in 67% and 20% of cases, respectively.

Figure 1 shows the actual estimates of TOF ratio in relation to the true TOF ratio as measured mechanically.

*Part 3.* During onset of neuromuscular blockade, fade was visually and manually perceptible at a mean TOF ratio of 0.51 and 0.66, respectively. During recovery the corresponding values were 0.57 and 0.66 (table 2). However, there was a wide scatter in the observations. Thus, "threshold fade ratio" varied between 0.28 and 0.95.

There was no significant difference between the figures for "threshold fade" whether this was evaluated visually, manually at the thumb, or with the observer's hand resting loosely in the hand of the patient.

## DISCUSSION

A TOF ratio of 0.70 is normally considered to reflect adequate recovery from a nondepolarizing block.<sup>6</sup> In view of this, our results indicate that it is very difficult, if not impossible, to estimate visually or manually a TOF ratio with sufficient certainty to exclude residual curarization. More specifically, the three major findings of our study are as follows: 1) Tactile evaluation of a TOF ratio (between 0.41 and 0.70) was associated with a high percent-

age of failure in identifying TOF fade. 2) Two years experience with nerve stimulators did not improve this result. 3) Tactile evaluation of TOF ratio was not improved

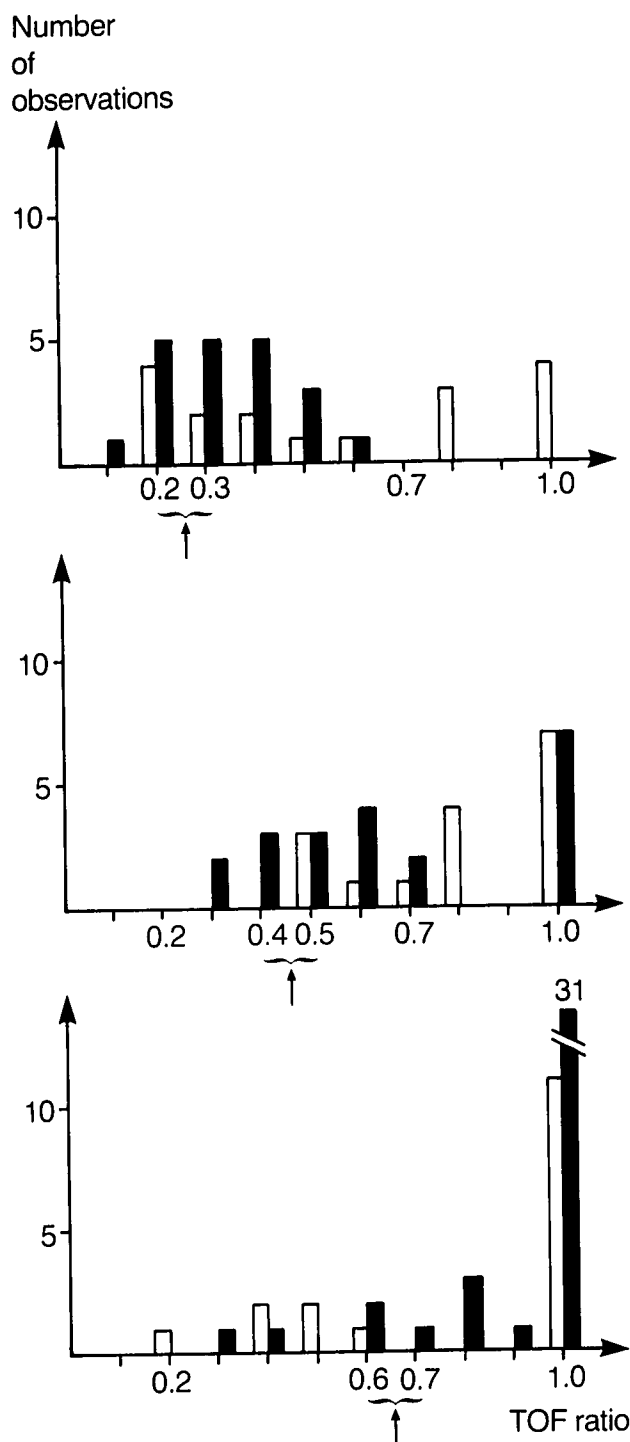


FIG. 1. Results of manual estimation of TOF ratio by moderately experienced observers (Group 2; open bars) and very experienced observers (Group 3; filled-in bars) in relation to the true TOF ratio as measured mechanically (indicated by the arrows). Note the wide scatter in estimated ratios. See text for further explanation.

TABLE 2. Evaluation of "Threshold Fade" by Three Very Experienced Observers

	Visual	Manual	
		Thumb	Hand
During onset	0.51* (0.38-0.73)	0.66 (0.42-0.92)	0.66 (0.46-0.95)
During recovery	0.57 (0.28-0.90)	0.66 (0.32-0.90)	0.66 (0.32-0.90)

\* Mean and ranges are given for TOF ratio at the time when fade in the response was either appearing (during onset) or disappearing (during recovery).

by feeling a control response or observing the response continuously during onset or recovery of neuromuscular block.

Parts 1 and 2 of the study were designed to imitate the conditions for evaluating a TOF response in the many departments in which nerve stimulators are not used routinely. In these departments the stimulator often is applied when a problem arises during recovery from anesthesia. The anesthetist, therefore, has no possibility of comparing the evoked response with a control response obtained before the injection of the neuromuscular blocking drug. Under these circumstances we found that neither the inexperienced nor the experienced observers were able to decide with sufficient certainty whether or not the neuromuscular block had adequately recovered. Even the two very experienced observers judged the neuromuscular block to have adequately recovered in 33% of cases with a true TOF ratio of 0.41-0.50 (table 1).

Part 3 of our study imitates the clinical situation in which the nerve stimulator has been attached to the patient before injection of the neuromuscular blocking agent to obtain a control value. Furthermore, the anesthetist knows when the neuromuscular blockade is expected to increase or decrease in intensity. The observers included in this part of the study were very experienced, but still there was a very wide scatter in "threshold fade ratio." Sometimes the observers could not see or feel fade when the TOF ratio was as low as 0.30-0.40. In other cases they indicated fade at TOF ratio of 0.90-0.95.

Our findings do not imply that TOF stimulation is useless unless monitoring equipment is available. The degree of surgical relaxation can be quantified simply by feeling the number of responses to stimulation<sup>1,3</sup> and overdosage of muscle relaxants thus avoided. Postoperative residual curarization is not likely to occur if the dose of muscle relaxant is guided by the response to TOF stimulation in this way and if the administration of the anticholinesterase agent at the end of operation is postponed until at least one and preferably two responses to the TOF stimulation are felt. Furthermore, in most clinical situations the degree of residual neuromuscular blockade can be evaluated

by the combined use of the response to nerve stimulation and clinical signs and symptoms of residual curarization.

In conclusion, manual evaluation of the response to TOF nerve stimulation is of value in the adjustment of individual dose regimens for neuromuscular blocking agents during anesthesia in order to avoid overdose and secure reversibility. However, postoperative absence of visual and manual fade in the TOF response does not exclude residual neuromuscular blockade.

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## Cricoid Compression is Effective in Obliterating the Esophageal Lumen in the Presence of a Nasogastric Tube

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Intravenous induction of anesthesia immediately followed by a full paralyzing dose of a muscle relaxant and tracheal intubation is a widely used technique for patients who are likely to vomit or regurgitate.<sup>1-3</sup> With complete muscle paralysis, vomiting cannot occur but regurgitation is possible.<sup>1-3</sup> To enhance the safety of the technique, Sellick,<sup>1</sup> in 1961, introduced cricoid compression to pre-

vent gastric contents from reaching the pharynx in case regurgitation occurs.<sup>1</sup> The maneuver consists of temporary occlusion of the upper esophagus by backward pressure of the cricoid ring against the bodies of the cervical vertebrae.<sup>1,2</sup> Despite the reliability of cricoid pressure, its efficacy in occluding the esophageal lumen in the presence of a nasogastric tube has been questioned.<sup>1</sup> Perhaps by tripping the sphincters at the upper and lower ends of the esophagus, a tube inside the esophagus may increase the risk of regurgitation.<sup>1</sup> Furthermore, this tube may interfere with obliteration of the upper esophageal lumen during cricoid compression.<sup>1</sup>

The present investigation was undertaken to determine the efficacy of cricoid compression in the presence of a nasogastric or an orogastric tube in adult cadavers.

#### METHODS

The study was approved by our committee on human investigations. Six fresh adult cadavers subjected to autopsies were studied. Authorization for postmortem examination and consent for the investigation were obtained from the next of kin. The stomach was exposed by an abdominothoracic incision. A mushroom gastrostomy or Foley catheter was inserted into the distal esophagus via the stomach. Tape was placed firmly around the esophagus to secure the catheter and prevent leakage distally. The catheter was connected to a three-way stopcock sys-

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