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Comparison of Double-burst and Train-of-four Stimulation to Assess Neuromuscular Blockade in Children

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Double-burst stimulation (DBS), a new technique to evaluate neuromuscular function, consists of two 50-Hz trains of 60-ms duration and 750 ms apart. DBS was compared with train-of-four (TOF) stimulation in 21 children aged 3–10 yr, during halothane anesthesia. On one arm the ulnar nerve was stimulated supramaximally with TOF stimulation every 12 s and the force of the evoked contraction of the adductor pollicis measured with an FTO3 force transducer and recorded on paper. Atracurium (0.4–0.5 mg · kg^{-1}) was administered. During recovery from neuromuscular blockade, TOF stimulation was interrupted periodically and DBS substituted. The same stimulation patterns were applied to the ulnar nerve of the other arm simultaneously, and the clinical anesthesiologist was asked to estimate the degree of fade with both. There was good correlation between the measured TOF ratio (ratio of fourth to first response) and DBS ratio (ratio of second to first response). The TOF and DBS ratios above which fade could no longer be appreciated manually were (mean ± SEM) 0.44 ± 0.03 and 0.67 ± 0.04 (P = 0.0002). Corresponding ranges were 0.3–0.8 for TOF and 0.4–0.9 for DBS, but DBS fade was always apparent if TOF fade could be detected. Therefore, in children, DBS is more sensitive than is TOF stimulation for the clinical assessment of recovery from neuromuscular blockade. (Key words: Anesthesia: pediatric. Monitoring: neuromuscular junction, double burst stimulation, train-of-four stimulation. Neuromuscular relaxants: atracurium. Neuromuscular transmission: double burst, train-of-four.)

RECOVERY FROM nondepolarizing neuromuscular blockade is commonly assessed clinically by observation of the force of contraction of the adductor pollicis of the thumb in response to train-of-four (TOF) stimulation of the ulnar nerve. A TOF ratio (the ratio of fourth to first twitch) of 0.7 or above is required before adequate return of respiratory function can be expected.[1,2] In adults it is difficult to detect fade visually or manually when the TOF ratio is above 0.3, causing the degree of paralysis to be underestimated.[3]

The technique of double-burst stimulation (DBS) has been introduced to obviate this shortcoming. It consists of two short tetani which are seen and felt as two contractions.[4,5] Various stimulation patterns have been used, but the best results have been obtained with two 50-Hz trains of 60-ms duration, 750 ms apart.[4] This study investigated the relationship between TOF and DBS responses in pediatric patients and the ability of clinicians to detect fade with the use of both of these monitoring techniques.

Methods

With approval from the Hospital Ethics Committee, 21 pediatric patients (aged 3–10 yr), ASA physical status 1 or 2, were studied during elective surgical procedures. Patients with hepatic, renal, or neuromuscular disease or on medication that could interfere with neuromuscular transmission were excluded from the study. No preanesthetic medication was administered. Anesthesia was induced with thiopental 3–6 mg · kg^{-1} intravenously and maintained with inhalation of nitrous oxide 70% and halothane 0.5–2% in oxygen.

One hand and forearm were immobilized in a splint and the force of contraction of the adductor pollicis measured with a Grass FT03 force displacement transducer and recorded on paper. The other arm was free. On both arms the ulnar nerve was stimulated supramaximally at the elbow with square wave pulses of 0.2-ms duration, and TOF impulses at 2 Hz were applied at 12-s intervals. This form of stimulation was interrupted and replaced with DBS with a Grass stimulator used to deliver two 50-Hz tetanic bursts of 60 ms and separated by 750 ms.[4,5] At least 12 s elapsed between the two stimulation patterns.

Baseline values for TOF and DBS recordings were established after induction of anesthesia, and then atracurium 0.4–0.5 mg · kg^{-1} was administered intravenously. The trachea was intubated 2 min later. Intermittent positive pressure ventilation was controlled to maintain normocapnia, and the inspired halothane concentration was maintained at 1%. During spontaneous recovery from neuromuscular blockade the clinical anesthesiologist was asked to assess the fade seen or felt after stimulation of the free arm, while a simultaneous recording of the response in the contralateral arm was made. The mode of stimulation (TOF or DBS) and the measured responses were hidden from the anesthesiologists making the observations.

The DBS ratio was measured at 0.1 increments of TOF ratio from 0.2 to 0.9 on each patient. The measured and observed DBS ratios were expressed as means ± SEM and 95% confidence limits for each 0.1 increment of TOF

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ratio. The TOF and DBS ratios when twitch fade could no longer be detected were compared by the paired Student's *t* test. A P value < 0.05 indicated statistically significant differences.

Results

Nine female and 12 male patients aged 3–10 yr were studied. The mean ± SEM age was 4.9 ± 0.4 yr and mean ± SEM weight was 18.2 ± 0.9 kg. The measured TOF and DBS ratios were numerically similar, and the relationship between these two values did not deviate significantly from the line of identify (fig. 1). The total number of paired tactile clinical observations was 170. Anesthesiologists tended systematically to overestimate recovery of the TOF and DBS ratios. This was more pronounced for TOF ($P < 0.05$ in the range 0.3–0.6) (fig. 2). At a mean measured TOF ratio of 0.44 ± 0.03, the anesthesiologist could no longer detect fade by visual or tactile means. With DBS, fade was detected until TOF reached 0.67 ± 0.04. The difference between these values was statistically significant, with $P = 0.00002$. In all cases, whenever TOF fade was detected clinically, DBS fade also was detected.

Discussion

The results of this study showed that the clinical use of TOF stimulation to assess recovery from neuromuscular blockade has the same limitations in children as it does in adults.[5] In the presence of appreciable neuromuscular blockade, TOF fade remained undetected by the observers, although all were experienced anesthesiologists who routinely use neuromuscular monitoring. The recorded values of DBS and TOF ratios were similar, and both patterns of stimulation identified the same degree of residual neuromuscular blockade. However, manual detection of DBS fade was made more easily than was that of TOF fade. Thus, DBS provided a more sensitive clinical indication of residual neuromuscular blockade. Although observers still overestimated recovery, the overestimation was less marked than with TOF stimulation.

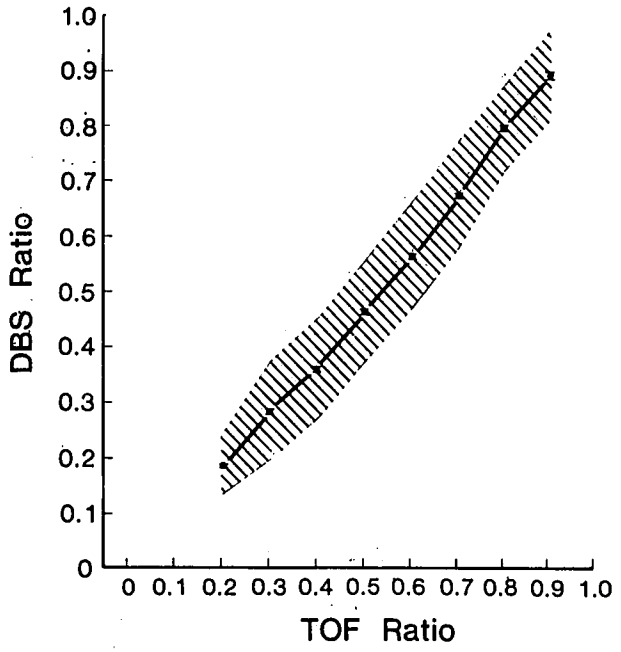

FIG. 1. DBS ratio (DBS2:DBS1) *versus* TOF ratio (T4:T1) at 0.1 increments of TOF ratio (values shown are means ± SEM with the 95% confidence limits for individual values).

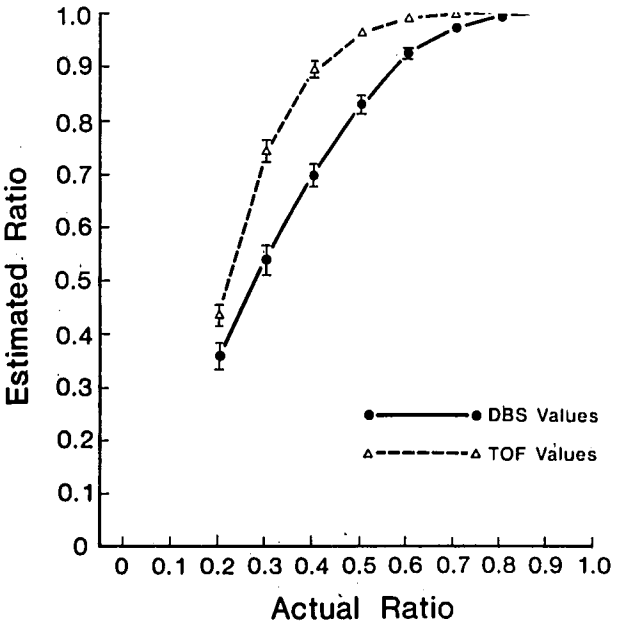

FIG. 2. Estimated TOF and DBS ratios *versus* measured ratios at 0.1 increments of TOF ratio (values shown are means ± SEM).

The detection rate for TOF fade in these pediatric patients is consistent with that reported in adults. Viby-Mogensen *et al.*[3] and Gill *et al.*[6] showed that for TOF fade in the range of 0.4–0.5, moderately experienced observers correctly identified fade in only 50% of instances. The current finding in children (that most observers could not detect fade when the TOF ratio was above 0.44) is similar. Fade was detected much more easily after DBS than it was after TOF stimulation. The mean TOF ratio associated with inability to detect DBS fade was 0.67. This is close to the value of 0.7, at which vital capacity returns to normal and inspiratory and expiratory force are decreased only slightly in volunteers given D-tubocurarine.[2] Also, this DBS ratio was similar to that reported in adults, in whom approximately 50% of observers could detect DBS fade in the TOF range 0.7–0.8.[6]

The superiority of DBS in the detection of residual blockade is not due to differences in the degree of fade of DBS and TOF, because both values of fade correlated well with each other and the regression line was close to the line of identity. It is more likely that other characteristics of DBS make this form of monitoring more suitable for the detection of residual paralysis. First, both DBS contractions are stronger than a single twitch, making DBS easier to detect. Second, it may be easier to compare the fourth with the first response in the TOF sequence when they are not separated by the second and third contractions.[5]

Residual neuromuscular blockade postoperatively is common in adults after the use of nondepolarizing muscle relaxants. TOF ratios less than 0.7 were measured in 42%[7] and 21%[8] of patients on arrival in the recovery room. This incidence was similar when peripheral nerve stimulation was used to guide dosage, with 30% of patients who received pancuronium demonstrating a TOF ratio of less than 0.7 in the recovery room.[9] The current study has confirmed that the use of TOF stimulation may fail to detect residual neuromuscular blockade of this degree by clinical assessment in children aged 3–10 yr. In this regard DBS appears to be superior. Thus, the availability of the latter modality would be a desirable feature in monitors designed for use in pediatric patients.

References

1. Ali HH, Katz RJ: Evaluation of recovery from non-depolarizing neuromuscular block using a digital neuromuscular analyzer: Preliminary report. Anesth Analg 52:740–743, 1973
2. Ali HH, Wilson RS, Savarese JJ, Katz RJ: The effect of tubocurarine on indirectly elicited train-of-four muscle response and respiratory measurement in humans. Br J Anaesth 47:470–573, 1975
3. Viby-Mogensen J, Jensen MH, Engbaek J, Ording H, Skorgaard LT, Chraemer-Jorgensen B: Tactile and visual evaluation of the response to train-of-four nerve stimulation. ANESTHESIOLOGY 63:440–443, 1985
4. Engbaek J, Ostergaard D, Viby-Mogensen J: Double burst stimulation (DBS): A new pattern of nerve stimulation to identify residual neuromuscular block. Br J Anaesth 62:274–278, 1989
5. Drenck NE, Ueda N, Olsen NV, Engbaek J, Jensen E, Skovgaard LT, Viby-Mogensen J: Manual evaluation of residual curarization using double burst stimulation: A comparison with train-of-four. ANESTHESIOLOGY 70:578–581, 1989
6. Gill SS, Donati F, Bevan DR: Tactile evaluation of the response to train-of-four and double burst stimulation. Can J Anaesth 36:S149–S150, 1989
7. Viby-Mogensen J, Chraemmer-Jorgensen B, Ording H: Residual curarization in the recovery room. ANESTHESIOLOGY 50:539–541, 1979
8. Beemer GH, Rozenthal P: Post-operative neuromuscular function. Anaesth Intensive Care 14:41–45, 1986
9. Bevan DR, Smith CE, Donati F: Post-operative neuromuscular blockade: a comparison between atracurium, vecuronium, and pancuronium. ANESTHESIOLOGY 69:272–276, 1988