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A Source of Errors in Assessing Neuromuscular Blockade

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The actions of muscle relaxants and their antagonists are commonly assessed by measuring the force of adduction of the thumb in response to stimulation of the ulnar nerve. The tetanic response is considered a more sensitive index of the degree of muscle paralysis than the single twitch because repetitive stimulation often uncovers appreciable muscle fatigue when single-twitch strength is relatively unaffected.[1-5]

During both tetanic electrical stimulation of the ulnar nerve and voluntary effort, the force of adduction of the thumb of the normal adult is 6–9 kg.[6-10] In many reported studies an inadequate instrument has been used, namely, the Grass FT-03 transducer, which according to manufacturer's specifications is capable of measuring a maximum of only 2 kg when fitted with the stiffest of four available springs.[11-23] A second transducer, the FT-10, will measure to 10 kg.

We calibrated one FT-03 and one FT-10 transducer using a set of accurate weights, a Grass polygraph, and an amplification system with the gain adjusted to give identical pen deflections when the transducers were each loaded with 2 kg. Figure 1 illustrates the results, which agree with the manufacturer's specifications and clearly show that the response of the FT-03 was limited to 2.2 kg, while that of the FT-10 was linear to 10 kg. Although neither transducer had perfect linearity, deviations were small enough to be of no clinical significance. The Grass FT-03 transducer, intended for use in small-animal studies, is patently inadequate for measuring the force of adduction of the thumb of the adult, because this force is three to five times greater than the measuring capability of the transducer.

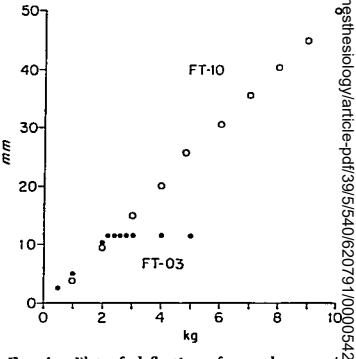

FIG. 1. Plot of deflection of recorder pen (y axis) versus applied load (x axis) for Grass FT-03 (dots) and FT-10 (circles) transducers.

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Received from the Anesthesia Research Center at the University of Washington School of Medicine, Seattle, Washington 98195. Accepted for publication March 13, 1973. Supported by USPHS Grant GM15991-03 (Anesthesia Research Center) from the National Institute of General Medical Sciences, National Institutes of Health.

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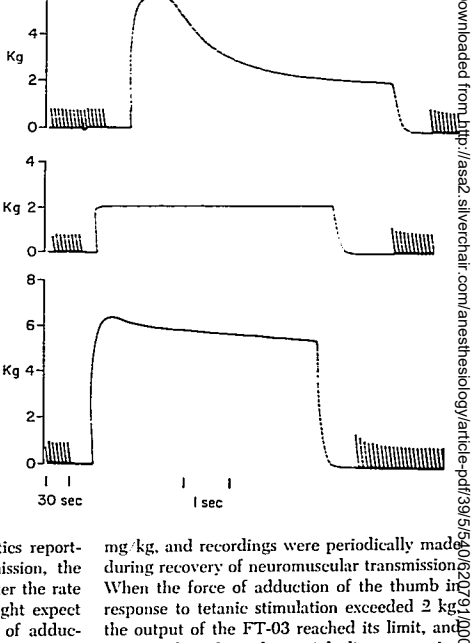

FIG. 2. *Bottom record:* Adduction force of the thumb during twitch and tetanic stimulation of the ulnar nerve in a 22-year-old man anesthetized with N_2O–morphine. FT-10 transducer. Note different time bases and slight fatigue. *Middle record:* Same patient recovering from *d*-tubocurarine, 0.3 mg/kg. FT-03 transducer. Note apparently well-sustained tetanic response and high twitch/tetanus ratio. *Top record:* Obtained 2 minutes after the preceding one, but with the FT-10 transducer. Note much higher initial force during tetany, fatigue, and lower twitch/tetanus ratio.

Since the potent volatile anesthetics reportedly depress neuromuscular transmission, the effect being more noticeable the faster the rate of neural stimulation,[19, 24-26] one might expect that in anesthetized man the force of adduction of the thumb could fall within the measuring range of the FT-03 transducer. Yet in 12 of our patients adequately anesthetized for operations on the perineum or lower extremities, seven with nitrous oxide–halothane and five with nitrous oxide–methoxyflurane, mean measured force of adduction of the thumb in response to tetanic electrical stimulation was 5.6 ± 1.4 kg, well above the capability of the FT-03. To demonstrate the importance of using an adequate transducer in determining the degree of neuromuscular block, we tested the FT-03 and the FT-10 in five patients anesthetized with nitrous oxide–morphine. In each patient we alternated transducers on one thumb, using a single recording system. The thumb was abducted approximately 45 degrees, thereby preloading the transducers by no more than 100 g. After control recordings of single-twitch and tetanic responses (50 Hz), the patients received *d*-tubocurarine, 0.3 mg/kg, and recordings were periodically made during recovery of neuromuscular transmission. When the force of adduction of the thumb in response to tetanic stimulation exceeded 2 kg, the output of the FT-03 reached its limit, and the recording showed a straight line, appearing to indicate sustained tetanus at a time when the FT-10 showed fatigue (fig. 2). Moreover, the tetanus/twitch ratio became distorted, for the record of twitch force continued to rise while that of tetanic force remained fixed at the limiting level of the FT-03 transducer.

When recovery of neuromuscular transmission or the effectiveness of a muscle-relaxant reversal drug is assessed by strength of tetanic response and degree of fatigue, measurement of the force of adduction of the thumb with the FT-03 transducer inevitably introduces three serious errors: 1) The control tetanic tension recorded before muscle-relaxant administration is falsely low and its true value remains unknown. 2) During recovery of neuromuscular transmission the tetanic tension appears to have recovered fully when in fact it may be less than half of the true control value. 3) The tetanic response looks well sus-

tained when fatigue is still present. These errors are present to some extent in all studies where the force of adduction of the thumb in response to tetanic stimulation has been measured with the FT-03 transducer, although they do not necessarily invalidate the conclusions.

The purpose of this paper is to make anesthesiologists aware of the relatively strong force of adduction of the human thumb and to induce them to calibrate strain gauges and include calibration scales in their recordings.

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