Anesthesiology
52:436–437, 1980

Variability in Assessment of Neuromuscular Blockade

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Optimal intraoperative skeletal muscle paralysis and its subsequent reversal are facilitated by accurate monitoring of nondepolarizing neuromuscular blockade.[1] This has been done by quantitating contraction of peripheral muscles in response to supramaximal nerve stimulation (ulnar, posterior tibial, facial)[2] by subcutaneous needle electrodes. Recently, disposable surface electrodes have been described as safe, effective, and convenient for use over the ulnar nerve.[3] When the arms are inaccessible intraoperatively, surface electrodes may also be used safely in the periorbital area with observation of facial nerve-mediated twitch. This study has compared the relative sensitivities of these three methods in assessing magnitude of neuromuscular blockade.

METHODS

The study was approved by our local committee on human research. Fifteen patients (ASA I, II, III) anesthetized with nitrous oxide, morphine, and thiopental were studied. *d*-Tubocurarine (*d*Tc) was used to produce neuromuscular blockade. None of the patients had received aminoglycosides, acetylcholinesterase inhibitors, ganglionic blockers, or magnesium prior to anesthesia. Commercially available, silver/silver chloride (NDM, American Hospital Supply) surface electrodes were placed: 1) over the ulnar nerve ("ulnar pads"), 2 cm and 9 cm proximal to the distal end of the ulna; 2) over the facial nerve ("facial pads"), 2 cm lateral to, and 2 cm above and below, the lateral canthus of the eye. Cardboard templates standardized electrode placement relative to anatomic landmarks, and the positive electrodes were always in the distal position. The eyelids were not taped on the side of the face being monitored. A third pair of electrodes, consisting of 25-gauge, metal-hub needles ("ulnar needles") was implanted subcutaneously beneath the ulnar pads. The same peripheral nerve stimulator (Output, Inc., Model FB-800) was used throughout the study.

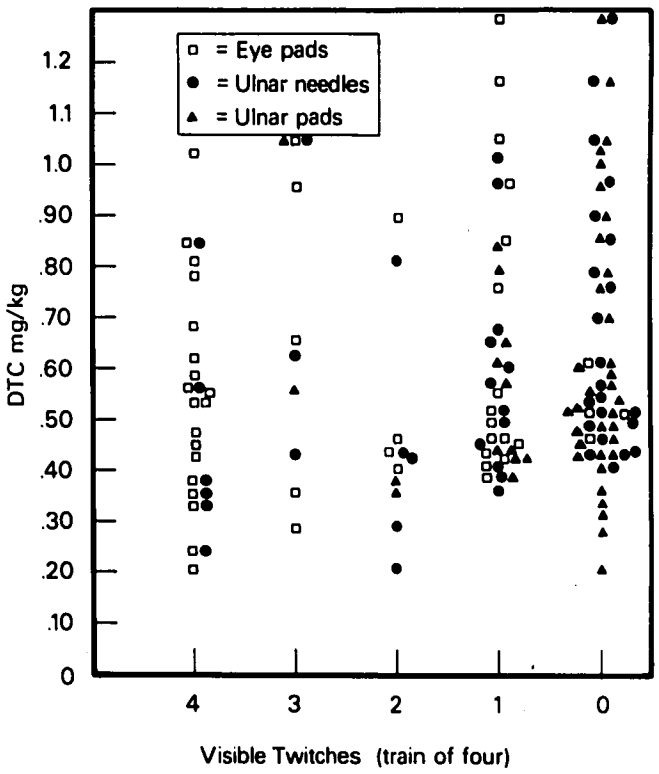

FIG. 1. Visible twitches by train-of-four technique dependent on cumulative dose of *d*-tubocurarine.

Nasopharyngeal temperatures varied between 35.0 and 37.5 C.

Prior to administration of the muscle relaxant, the response to train-of-four stimulation[4] at each electrode pair was observed. The numbers of hand (fingers or hypothenar eminence) and facial (eyelids or supraorbital ridge) twitches observed were recorded. All patients received 3 mg *d*Tc, and 1.5 mg/kg succinylcholine to facilitate tracheal intubation. After full twitch recovery, doses of *d*Tc were given intravenously according to the clinical judgement of the anesthesiologists. Ten minutes after each dose, train-of-four stimuli were applied sequentially to the ulnar pads, facial pads, and ulnar needles. Three minutes were allowed between ulnar pad and ulnar needle stimulation, although one-minute intervals adequately prevented "train-of-four" evidence of ulnar nerve fatigue. Eight additional patients were similarly studied after administration of succinylcholine (SCh), 5 mg/kg, by rapid intravenous in-

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Received from the Department of Anesthesiology, University of Arizona Health Sciences Center, Tucson, Arizona 85724. Accepted for publication December 5, 1979.

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fusion. A nondepolarizing relaxant had not been given previously in this group. Times between disappearance of all ulnar pad twitches (first to be suppressed) and reappearance of four twitches at all electrode sites were recorded.

Data from the patients who received *d*Tc were analyzed by inferences from proportions using the binomial distribution[5] to test the average twitch response at each electrode site. Subthreshold doses of *d*Tc that did not eliminate at least one twitch at any electrode site were excluded from the analysis. Data from the patients who received SCh were analyzed by the Student *t* test for paired data.

Results

In all 47 sets of measurements from the 15 patients who received *d*Tc, the numbers of twitches seen after concurrent train-of-four stimulation conformed to the following relationship: [facial pads] ≥ [ulnar needles] ≥ [ulnar pads] ($P < 0.001$; binomial distribution). Doses of *d*Tc that reduced ulnar needle-mediated train-of-four to one visible twitch reduced ulnar pad-mediated train-of-four to zero twitches in 75 per cent of concurrent measurements and resulted in facial pad-mediated twitches of three or four in 67 per cent of concurrent measurements (fig. 1).

In all patients who received SCh, there was rapid onset of complete twitch depression at all three stimulating sites. The average times from the onset of complete twitch depression to reappearance of four distinct twitches were (±SEM): facial pads 7.75 ± 0.92 min; ulnar needles 12.0 ± 1.0 min; ulnar pads 14.1 ± 1.4 min. Recovery time for facial pads was significantly less than that for ulnar needles or ulnar pads ($P < 0.005$).

Discussion

The results of our study indicate that responses to train-of-four peripheral nerve stimulation consistently vary with the type and location of the electrodes. The use of ulnar surface electrodes provides an excessive estimate of the extent of neuromuscular block, thus increasing the possibility of inadequate muscle relaxation in the presence of profound twitch depression. This may be due to the inability of commercial peripheral nerve stimulators to stimulate the ulnar nerve supramaximally when surface electrodes are used (Blitt *et al.*, unpublished data). In contrast, visible facial twitch (surface electrodes) often coexisted with profound ulnar needle-mediated twitch depression, and consequently with high degrees of receptor occupancy.[6,7]

This study shows that, using the train-of-four technique, assessment of neuromuscular blockade with *d*-tubocurarine and succinylcholine varies depending on the site and type of twitch-monitoring electrodes. Compared with standard ulnar needle electrodes, ulnar surface electrodes tend to overestimate, and periorbital surface electrodes to underestimate, the neuromuscular block. Knowledge of the relative sensitivities of these three methods may foster accurate monitoring of neuromuscular blockade, regardless of the method employed.

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