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Neuromuscular Blockade Monitoring Comparing the Orbicularis Oculi and Adductor Pollicis Muscles

RICHARD R. CAFFREY, M.D.,* MARVIN L. WARREN, M.D.,† AND KARL E. BECKER, JR., M.D.‡

Monitoring of neuromuscular (NM) function has become increasingly important with the advent of intermediate-acting, nondepolarizing muscle relaxants such as vecuronium and atracurium. Extensive developmental and clinical usage has shown that these commercially available intermediate relaxants are reasonably predictable in duration of action but still subject to individual variations.[1,2] Some of the factors contributing to these variations include hypothermia, electrolyte imbalances, NM diseases, drug interactions, and the method of NM blockade monitoring.[3] A previous study has examined the influence of site on NM blockade monitoring during depolarizing blockade and during onset of NM blockade with *d*-tubocurarine.[4] We examined a similar variable during the recovery phase of nondepolarizing NM blockade with atracurium.

MATERIALS AND METHODS

Nine patients undergoing surgical procedures normally requiring muscle relaxation were monitored for both facial and adductor pollicis twitches in response to stimulation of the facial and ulnar nerves. Approval of this study was obtained from the hospital Human Research Committee. Patients ranged in age from 26 to 78 yr. Markedly obese patients and patients with NM disease were excluded. All patients were ASA Class I or II. Premedication consisted of meperidine 25 mg (0.27–0.44 mg/kg), diazepam 2.5 mg (0.027–0.044 mg/kg), and atropine 0.2 mg (0.002–0.003 mg/kg) iv. Anesthesia was induced with thiopental, 5 mg/kg, and succinylcholine, 1.5 mg/kg iv. Intubation of the trachea was performed and the thumb twitch height was allowed to return to the level determined prior to administration of other muscle relaxants. Anesthesia was maintained with enflurane at a vaporizer setting of 2.0–2.5% and 50% N_2O/O_2.

Atracurium was titrated to complete obliteration of single twitch and tetanic responses to stimulation of the facial and ulnar nerves. Twitch and tetanic responses were then allowed to recover spontaneously. During this recovery period, train-of-four (TOF) stimuli were applied to the facial and ulnar nerves about every 2 min and any change was recorded. Tetanic stimulations were occasionally performed to help assess questionable responses to TOF stimulations, although they were not regularly monitored. A minimum of 30 s was allowed between tetanic stimulations and further evaluations. One patient exhibiting continued response to stimulation after initial doses of atracurium was considered to be exhibiting direct muscle stimulation and was excluded from the study. Patients requiring reversal or redosing of atracurium before recovery of four twitches in the hand and face were excluded from the study.

Stimulation of the ulnar and facial nerves was performed *via* Plia Cell® ECG electrodes (NDM Corp., Dayton, OH) connected to Mini-Stim® nerve stimulators (Model MS-1, Professional Instruments Co., Houston, TX), which provide a 2 Hz supramaximal stimulus with a square wave, monophasic pulse. The electrodes were placed over the ulnar nerve at the wrist and over the facial nerve lateral and inferior to the eye with care to avoid direct muscular stimulation as discussed previously. The negative electrodes were always placed distally.

Monitoring involved attaching a linear force transducer (no. 11601-7, Interface Corp., 250-lb maximum capacity) to the thumb and forearm after the method of Ali and Savarese.[3] A more sensitive linear force transducer (no. 1196, Lebow Corp., 5-lb capacity), suspended from a frame constructed for the study, was taped to the eyebrow *via* a rigid connector to allow recording of forces away from or toward the transducer. The frame was secured to the bed to hold the transducer motionless relative to the eyebrow (fig. 1). The transducers were connected to a recorder to provide a written record of the twitch tension.

Analysis of the data obtained was performed using Student's one-tailed *t* test. A *P* value of <0.05 was considered to be statistically significant.

* Resident in Anesthesiology, University of Kansas School of Medicine, Wichita.

† Staff Anesthesiologist, St. Joseph Medical Center.

‡ Associate Professor, Department of Anesthesiology, University of Kansas School of Medicine, Wichita.

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Address reprint requests to Dr. Becker, Department of Anesthesiology, University of Kansas, 929 North St. Francis, Wichita, Kansas 67214.

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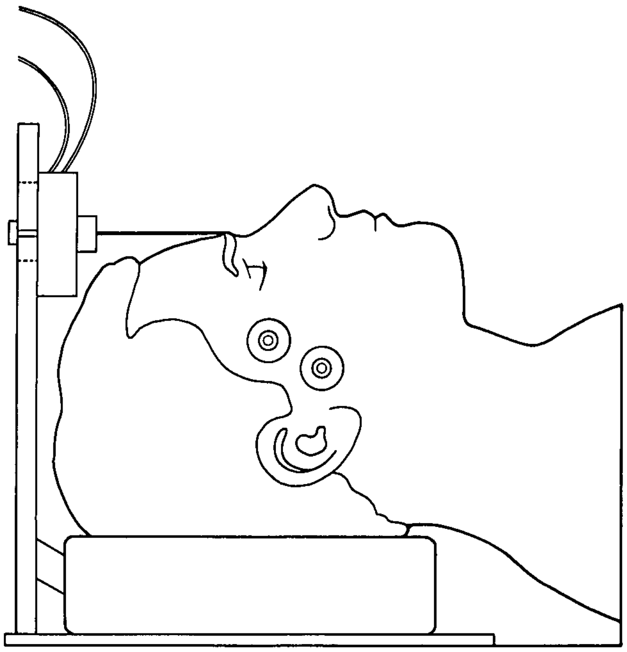

FIG. 1. Positioning of stimulating electrodes and force transducer on the face.

RESULTS

In all cases, initial and fourth twitches returned to the orbicularis oculi muscles before returning to the adductor pollicis muscles (table 1). The initial twitch returned to

TABLE 1. Times (min) to Recovery of One and Four Twitches in the Face and Hand

Patient	Recovery of One Twitch*		Recovery of Four Twitches†	
	Face	Hand	Face	Hand
1	13	20	18	42
2	14	25	17	35
3	18	37	29	‡
4	10	26	10	35
5	21	40	29	45
6	25	42	46	55
7	35	50	46	54
8	28	31	41	60
9	36	44	43	‡

* Mean ± SD = 22.2 ± 9.5 min for face and 35.0 ± 10.0 min for hand; $P < 0.01$.

† Mean ± SD = 29.4 ± 14.8 min for face and 46.4 ± 10.2 min for hand; $P < 0.05$.

‡ Neuromuscular blockade antagonized prior to this observation, face and hand values excluded from calculations.

the face an average of 12.8 (±5.8 SD) min before initial recovery of twitch in the thumb ($P < 0.01$). The fourth twitch began to appear in the face 17.0 (±6.2 SD) min prior to appearance in the thumb ($P < 0.05$). See figure 2 for a diagram of typical responses to stimulation.

DISCUSSION

Comparison of ulnar and facial nerve TOF stimulation during recovery from depolarizing (succinylcholine)

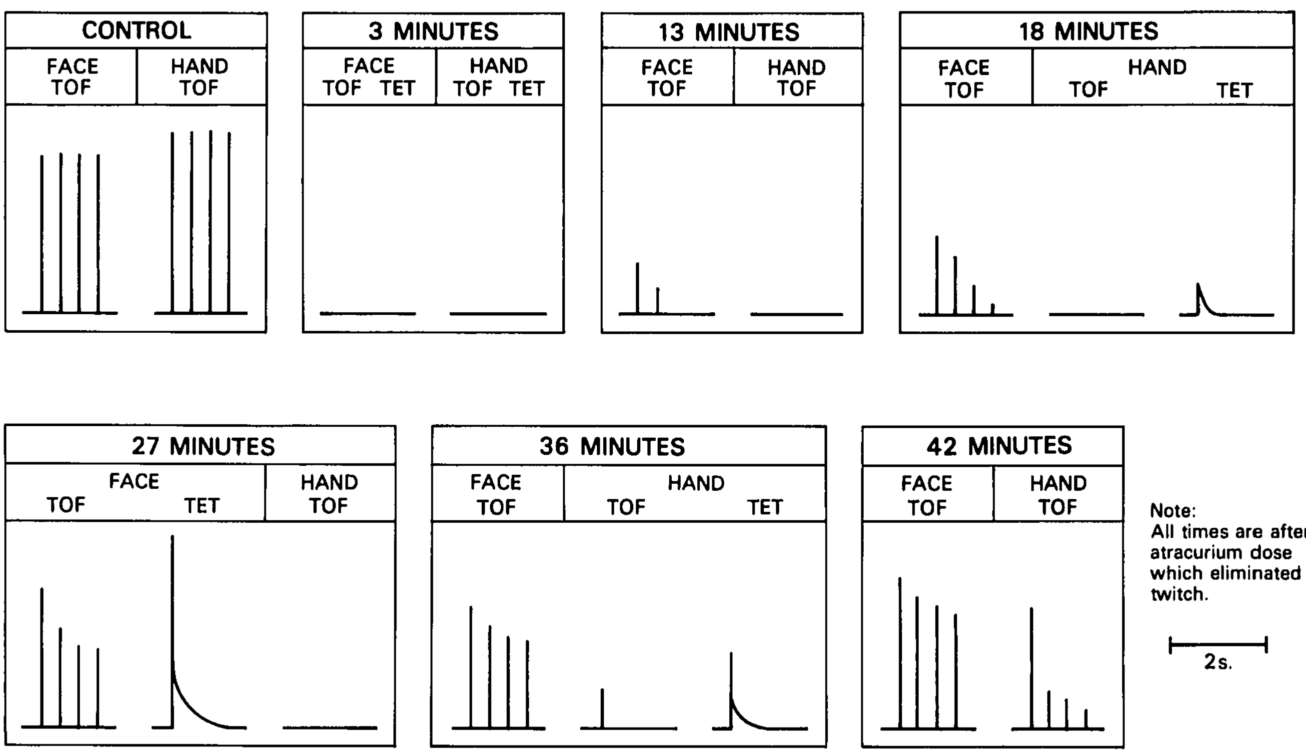

FIG. 2. Diagram of typical train-of-four (TOF) and tetanic (TET) responses to stimulation.

blockade and during onset of partial nondepolarizing (*d*-tubocurarine) blockade has been reported by Stiffel *et al.*[4] Some differences in results of TOF stimulation would be expected between depolarizing and nondepolarizing blockade and between onset and recovery from nondepolarizing blockade.[5] Despite these expected differences, the finding of Stiffel *et al.* of relative underestimation of NM blockade at the facial nerve site tends to support our determinations made during recovery from atracurium. The clinical implications of the more rapid recovery of TOF responses in the face with regard to redosing intervals and the need for antagonism of NM blockade at the end of the case are apparent. The basis of this relative facial insensitivity to NM blockade, however, remains uncertain. Possible explanations would include both anatomic and equipment variables.

A different type of innervation is found in the extraocular muscles and in some muscles of expression in the face and neck. These muscles have a larger number of NM junctions compared with other muscles of the body. This may contribute to their more rapid return to functioning.

Equipment variables include positioning of the electrodes and delivery of an adequate stimulating impulse. A discussion of the measures we took to avoid direct facial muscle stimulation by careful electrode placement and by achieving complete blockade is included in "Methods". One patient was excluded from our study based on inability to abolish completely responses to facial stimulation. Complete abolition of twitches was performed only with succinylcholine in the study by Stiffel *et al.* Although it is doubtful that this caused any serious inaccuracies in their results, confusing responses can appear clinically if the possibility of direct muscular stimulation is not considered.

Care was taken in placing the ulnar electrodes to achieve the greatest possible response to stimulation because variations in placement and polarity of the electrodes can affect evoked responses.[6] The use of surface electrodes over the ulnar nerve tended to overestimate the degree of blockade compared with needle electrodes in another portion of the study by Stiffel *et al.* Statistical significance of the difference noted during recovery of TOF responses, however, was not reported. All electrodes used in our study were checked for moist contact pads to minimize skin resistance because increases in resistance can decrease output current from many nerve stimulators.[7]

The nerve stimulators chosen for use in our study reflect our intent to maintain clinical conditions. Although not laboratory grade equipment, all of the stimulators used produced consistent output impulses of adequate current (45 mA into 470 ohms over 0.2 ms) to stimulate supramaximally the ulnar nerve of most patients *via* surface electrodes.[8] An additional internal control was provided by using the same stimulator at both sites for all but two patients on whom two stimulators were used. The force transducers were tested for linearity of response over their active ranges and found to produce consistent results. Variations produced by this selection of equipment would be reproduced in clinical usage of similar nerve stimulators and expected to produce results similar to those reported here.

Based on this study, we conclude that the facial nerve–orbicularis oculi muscle system recovers more rapidly from atracurium than the ulnar nerve–adductor pollicis muscle system. Managing NM blockade by stimulation of the facial nerve should provide relaxation at least equal to that determined at the ulnar nerve. However, caution should be used when using facial nerve stimulation to assess reversal of an atracurium NM blockade. The twitch and TOF response may have completely recovered and yet still have a significant atracurium NM blockade present by other criteria (*e.g.*, ulnar nerve stimulation, head lift).

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