TITLE: QUANTITATIVE COMPARISON OF THENAR ELECTROMYOGRAPHIC AND FORCE DISPLACEMENT SIGNALS DURING AUTOMATED VECURONIUM INFUSION

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Introduction: Methodologic concerns preclude precise conclusions regarding published quantitative comparisons between force displacement (FD) and electromyographic (EMG) signals.[1] Employing an automated, feedback control system[2] for the infusion of vecuronium, these signals were compared simultaneously.

Methods: Following Institutional Review Board approval and informed consent, 16 patients were prospectively studied. Patients with neuromuscular disorders or those taking medications affecting the neuromuscular junction were not included. **Anesthesia:** Premedication with diazepam and ranitadine was followed by induction with thiopental, 2-5 $mg \cdot kg^{-1}$ I.V. Laryngoscopy was facilitated with succinylcholine, 1 $mg \cdot kg^{-1}$ I.V., and steady state anesthetic maintenance was achieved with an end-tidal concentration of 1.0-1.3 MAC of enflurane or isoflurane, measured by mass spectrometry. **Neuromuscular Blockade:** Upon receipt of a trigger signal from the controller, a Grass S-48 nerve stimulator delivered a supermaximal voltage pulse via a stimulus isolation unit to the ulnar nerve at the wrist. The evoked thenar EMG was amplified, rectified, and integrated by an EMG processor. Concurrently, the evoked isometric twitch tension of the adductor pollicis muscle was measured with a Grass FT-10 linear FD transducer, with the thenar preload adjusted to 250 grams. The voltage proportional output of each signal acquisition device was displayed digitally on the CRT screen, one was sampled and guided the vecuronium infusion, while both were concurrently recorded every 10 seconds. Each signal was displayed as 1.00, and any depression of the signal was indicated by that percentage of 1.00 (i.e., 90% depression equals 0.10). Patients were randomly allocated to either the EMG or FD group, indicative of the signal used to close the feedback control loop. The controller was implemented on an S-100 based microcomputer equipped with A-D and D-A convertors. After the baseline signals were established, the controller executed the program, which employed a proportional-derivative (PD) algorithm for vecuronium and signalled an IMED 929 computer-driven infusion pump. The desired degree of signal depression for all patients was 90%. Initially, the patient's name, weight, age, and sex were entered into the controller, and the time, infusion rate, and percent of control EMG and FD were recorded at 10 second intervals throughout each case. When possible, neuromuscular activity was permitted to recover spontaneously; however, when clinically necessary, anticholinesterases were administered. Data was analyzed using three-way analysis of variance.

Results: Age, weight, gender, and physical status were comparable between the groups. Data presented in the table represents 12,363 comparisons of the EMG and FD signals. Regardless of the signal closing the loop (EMG or FD), the EMG uniformly persisted as the larger signal during the induction of neuromuscular blockade, with these differences even increasing during the recovery from relaxation. The EMG was less sensitive than the FD signal to vecuronium-induced depression, and manifested an overshoot of control of up to 25% during either spontaneous or pharmacologic induced recovery.

Discussion: Devices for practical quantitation of thenar force displacement in the clinical arena have limited use and availability, while visual assessments are notoriously inaccurate. In this study, the EMG signal was invariably larger, suggesting that this signal is less sensitive to depression by neuromuscular blocking drugs than the FD signal. Anesthesiologists monitoring the EMG can expect to use larger doses than those quoted for an equivalent degree of FD depression. Furthermore, return of the EMG signal to control did not coincide with the recovery of baseline FD signal. At times when the EMG signal was at 125% of control, the FD signal had not returned to baseline, indicating the need for other tests substantiating the adequacy of neuromuscular transmission when this monitor is employed.

Table

Comparison Between EMG (electromyogram) and FD (force displacement) Signals During Vecuronium Infusion (Mean ± SEM)

DEPRESSION %	SIGNAL DIFFERENCE	
	FD Loop (n = 8)	EMG Loop (n = 8)
Induction		
-10	0.04 ± 0.03	0.10 ± 0.02
-30	0.13 ± 0.03	0.16 ± 0.02
-50	0.16 ± 0.03	0.19 ± 0.02
-70	0.18 ± 0.03	0.18 ± 0.02
-90	0.11 ± 0.03	0.10 ± 0.02
Recovery		
-90	0.11 ± 0.03	0.10 ± 0.02
-70	0.29 ± 0.04	0.19 ± 0.03
-50	0.30 ± 0.03	0.25 ± 0.03
-30	0.30 ± 0.04	0.31 ± 0.03
-10	0.33 ± 0.08	0.37 ± 0.03
+10		0.45 ± 0.03

Depression = % depression of control feedback loop signal (EMG or FD). Signal difference = thenar EMG (% control) minus thenar FD (% control). EMG loop, FD loop = feedback control loop closed by EMG or FD, respectively. Induction = initiation of neuromuscular block from 100% to 10% of control signal. Recovery = restoration of control signal. At each degree of depression, EMG and FD signals were significantly different from each other, $p < 0.01$.

References:

1. Kopman AF: The relationship of evoked electromyographic and mechanical responses following atracurium in humans. Anesth 63:208-211, 1985

2. Ebert J, Carroll SK, Bradley EL, Jr.: Closed loop feedback control of muscle relaxation with vecuronium in surgical patients. Anesth Analg 65:S44, 1986