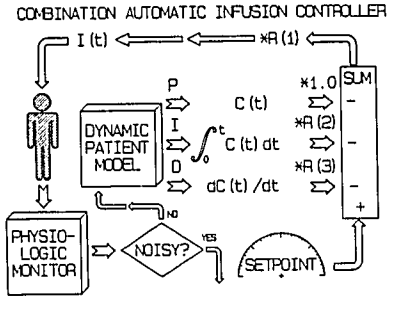
Title: AUTOMATIC COMPUTER CONTROL OF NEUROMUSCULAR BLOCKADE

Authors: T. J. Quill, M.D., J. G. Reves, M.D., J. R. Jacobs, Ph.D., and P. S. Glass, M.D.

Affiliation: Department of Anesthesiology
Duke University Medical Center
Durham, NC 27710

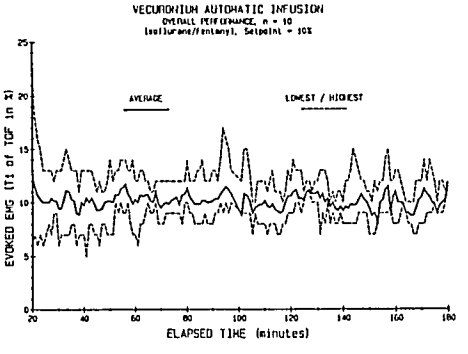
Introduction: This study investigates the theoretical and practical aspects of a closed-loop device for the automatic control of surgical neuromuscular blockade. A complete system for the automatic administration of vecuronium was designed, tested, and compared with manual vecuronium infusions.

Methods: A mathematical model based upon two-compartment pharmacokinetics closely simulating the average ulnar evoked electromyograph single-dose response of vecuronium was developed using fractional dose response data provided by the manufacturer and single dose response data from a pilot study of 6 healthy patients. The model was then used in computer simulations to empirically adjust and modify the parameters of a PID (proportional-integral-derivative) adaptive controller in order to achieve rapid onset and overall stability for the maintenance of neuromuscular blockade during surgery.



Following institutional approval and informed consent, 40 general surgical patients were selected for the study. Roughly half received a nitrous oxide-fentanyl general anesthetic, and the remainder a volatile agent. In all cases, vecuronium was automatically administered using the previously developed controller for both induction and maintenance of neuromuscular blockade using a Puritan-Bennett AB-100 evoked EMG unit, an IBM PC-XT, and an Abbott computer controlled infusion pump. The controller objective was to reach and maintain the "T1 value" (of the evoked train-of-four) at 10% of calibration level. Controller parameters initially required slight adjustment to achieve optimal stability for all patients. The model was not changed or adjusted for any of the last 20 patients, with the only required initial parameter being the patient weight. Simple "adaptive" control was achieved by automatic variation in the overall controller proportional gain, depending upon observed individual response.

Results: Data from the first 20 patients shows expected moderate fluctuations in controller stability, since the parameters and basic design were being experimentallly adjusted from patient-to-patient to improve performance. The final 20 patients, however, displayed a rapid onset of neuromuscular blockade, with intubation at 6 minutes +/- 1 minute, and stable maintenance of neuromuscular blockade at 10% +/- 1.5% (S.D.) in all patients after 20 minutes, without any changes in the basic design or internal parameters. The average infusion rate showed a significant decrease with time ($p < 0.01$). Infusion rate data was not significantly different from previous manual data, although the automatic controller made more frequent and wider adjustments.



Discussion: The ability to control surgical neuromuscular blockade using an automatically controlled vecuronium infusion was demonstrated. A constant and adequate level of relaxation was rapidly reached and maintained within narrow limits.

References:
1. Asbury A, Linkens D: Clinical automatic control of neuromuscular blockade. Anaesthesia 41:316-320, 1986
2. Ritchie et al: A microcomputer based controller for neuromuscular block during surgery. Ann. Biomed. Engr. 13:3-15, 1985