

Automatic control of neuromuscular block during long-lasting neurosurgical interventions in geriatric patients - what we can learn from the computer

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Background

Neuromuscular blockade (NMB) is an essential part of balanced anaesthesia. However, widespread use of muscle relaxants (NMBA, neuromuscular blocking agent), often based on empiricism and superficial look at the commercial information, is frequently associated with unacceptably high incidence of adverse effects. The ease of intravenous injection of muscle relaxant, resulting in neuromuscular block, contrasts with clinically serious consequences following its application (1). The variability in the effect of NMBA is substantial and may be increased in the elderly patients (2).

In current anaesthetic practice, the maintenance of muscle relaxation for long surgical procedures can be achieved in two ways. After an initial bolus of non-depolarizing NMBA to facilitate tracheal intubation the blockade may be ensured by either further increments (top-ups) or continuous infusion of the relaxant. While a continuous relaxant infusion is an appropriate technique for long-lasting operations, infusion rates need to be adjusted repeatedly to maintain a given level of neuromuscular blockade and a manual control of pump speed is time-consuming. If this adjustment is performed automatically, the anaesthetist is freed to attend to other aspects of patient care (3).

Goal

To compare the dose of rocuronium and cisatracurium administered continuously in younger and elderly male patients undergoing long neurosurgical procedures under total intravenous anaesthesia (midazolam, propofol, sufentanil, O₂/air, rocuronium or cisatracurium).

Technical description (3) – Fig. 1

We used closed-loop system for automatic control of neuromuscular blockade. The degree of block (TOF-ratio, T₁) was determined in 10 sec intervals using Datex-Ohmeda S/5TM monitor wirelessly interfaced to a PC for data collection; the computer was programmed to ensure a stable level (target T₁ = 10 % of baseline) of block by controlling the infusion pump with rocuronium or cisatracurium, respectively. The algorithm of the regulation was based on the anaesthetist's expertise and fuzzy logic. Before induction of anaesthesia, the anaesthetist enters the input data (patient's body weight, concentration of NMBA in the syringe and target level of the neuromuscular block). After the induction of general anaesthesia but before the administration of muscle relaxant, the NMT monitor was calibrated using the automatic start-up procedure; the initial intubating dose and maintenance infusion of NMBA was ensured entirely by the system. If delayed extubation was not planned, the system was stopped and spontaneous recovery allowed at the end of anaesthesia. Numerous safety measures, hierarchical alarms and rescue steps are implemented in both hardware and software components of the system.

The main studied parameter was consumption of NMBA (mg kg⁻¹ hr⁻¹) during regulation phase (PC-controlled infusion of either rocuronium or cisatracurium). The interval from stopping the system to spontaneous recovery of TOF-ratio above 0.9 and the number of patients requiring reversal with neostigmine were recorded, too.

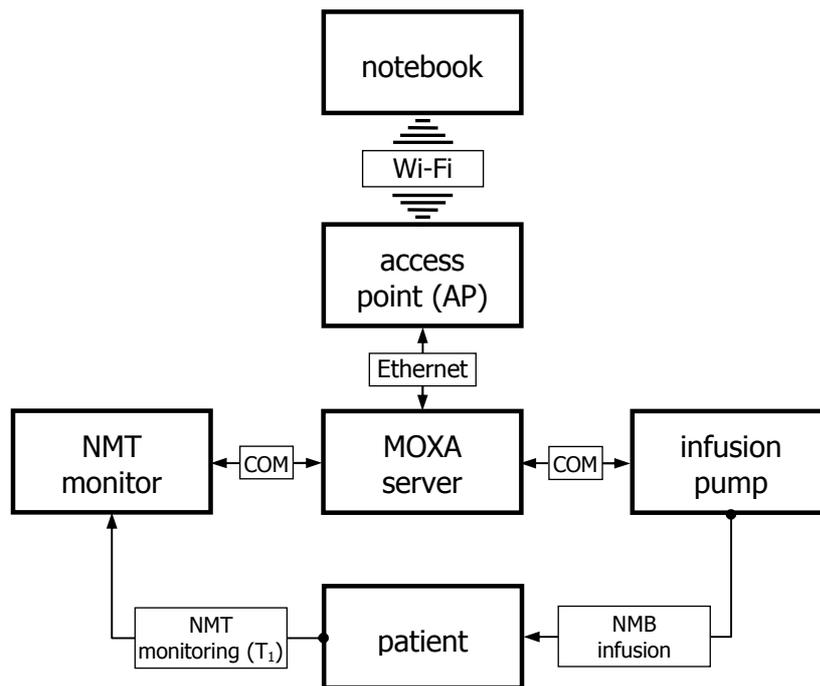


Fig. 1
Hardware part of the system for automatic control of neuromuscular block
COM serial port, Wi-Fi wireless communication

Patients and Results

Table 1

Comparison of rocuronium and cisatracurium in adult and elderly patients. Age, consumption of NMBA during regulation phase, length of regulation phase, interval from stopping the system to TOF-ratio 0.9 are given as medians and 95% confidence intervals.

	adult (18-64 yrs)	elderly (≥ 65 yrs)	<i>p</i> -value
rocuronium			
n	42	29	
age (years)	46 [38; 47]	72 [70; 74]	< 0.001
consumption (mg kg ⁻¹ hr ⁻¹)	0.34 [0.30; 0.38]	0.26 [0.20; 0.32]	0.02
length of regulation phase (hr)	225 [179; 271]	200 [161; 239]	0.44
T ₁ – TOF-ratio 0.9 (min)	18 [15; 19]	24 [22; 28]	< 0.001
neostigmine required (cases)	15 (36 %)	17 (59 %)	0.09
cisatracurium			
n	36	30	
age (years)	48 [40; 49]	71 [69; 74]	< 0.001
consumption (µg kg ⁻¹ hr ⁻¹)	60 [58; 66]	52 [45; 61]	0.14
length of regulation phase (hr)	200 [162; 244]	193 [160; 226]	0.80
T ₁ – TOF-ratio 0.9 (min)	17 [16; 20]	19 [17; 23]	0.28
neostigmine required (cases)	10 (28 %)	12 (40 %)	0.31

The system was able to maintain a stable level of neuromuscular blockade throughout general anaesthesia for long neurosurgical procedures in both younger and elderly males. As no human

intervention was needed during the regulation, the clinical workload of the anaesthetist was reduced. Controlling the depth of neuromuscular block in an automatic way improved the efficacy of muscle relaxant delivery and enabled the patient to receive a minimum amount of drug.

A considerable feature of the system is its flexibility: During regulation phase, the selected target level of neuromuscular block ($T_1 = 10\%$) is both deep enough for enabling surgery and not so excessive as to prolong the recovery from the block. Following the switching off the infusion pump, full muscle strength either recovers spontaneously or this procedure can be accelerated with reversal agent (neostigmine). Typically, this strategy allows the anaesthetist to terminate the neuromuscular blockade within 15–20 minutes irrespective of the regulation phase duration. For junior anaesthetists, the automatic system can be used as a “teacher” or a “guide” to the muscle relaxant administration strategy. This relates to a broader aspect of using fuzzy logic in medicine. Namely, a fuzzy logic model reveals the structure of medical knowledge, makes it explicit but still close to understanding of a medical doctor.

Conclusions

In **all** patients (both younger and elderly), there is a significant interindividual variability in the effect of both rocuronium and cisatracurium during continuous infusion of NMBA.

Compared to younger adults, the rocuronium consumption in elderly patients is lower during maintenance of the blockade. The interval from switching off the system to recovery of TOF-ratio above 0.9 was prolonged in geriatric patients receiving rocuronium. For cisatracurium, the differences between younger and elderly patients could not be demonstrated. Nevertheless, 28–40 % (cisatracurium) and 36–59 % (rocuronium) patients required neostigmine for reversal [this is comparable to (4)].

NMBAs are valuable drugs but their effect is unpredictable. This reality constitutes a rationale for monitoring of neuromuscular blockade during anaesthesia (5-8). When the NMB is administered, peripheral nerve stimulator with quantitative (objective) evaluation of evoked muscle response should be used. This is *conditio sine qua non* of safe general anaesthesia with NMBA.

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