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ORIGINAL RESEARCH
ОРИГИНАЛЬНОЕ ИССЛЕДОВАНИЕ

Monitoring of Neuromuscular block during emergency abdominal surgery

Neelam Dhunputh ✉, **Marina V. Petrova**, **Victor V. Moroz**, **Andrey V. Butrov**, **Marat A. Magomedov**

RUDN University, *Moscow, Russian Federation*
✉ dhunputhneelam@gmail.com

Abstract. *Relevance.* Sixty percent of cases of residual neuromuscular block (rNMB) were recorded globally, yet this issue of rNMB in critically ill patients remains taboo. To predict any leftover NMB, a train-of-four stimulation (TOF) Watch SX was utilized to track the depth of muscle relaxant in emergency patients both during and after surgery, even when they were transported to the intensive care unit. *This study aimed* to investigate differences in the variability of neuromuscular block between two distinct surgical procedures: laparoscopic cholecystectomy (the control group) and emergency abdominal surgery (the investigation group). *Materials and Methods.* Using two different muscle relaxants and assessing their depth using accelerometry notably the TOF Watch SX. A total of 140 patients, aged 18–60 years with a BMI of 18–30 kg/m², participated in the study. Group I underwent planned cholecystectomy (control group), while Group II underwent emergency abdominal surgery (investigation group). The muscle relaxants Ridelat-C, generic of atracurium benzilate (Verofarm OOO, Harabovsk, Russia) and Kruaron, generic of rocuronium bromide (Verofarm OOO, Harabovsk, Russia) were administered, with various monitoring methods, including Drager Fabius, ECG, and lab results, Microsoft Office Professional Plus 2021 advanced with graphs and ANOVA. *Results and Discussion.* The results demonstrated profound skeletal muscle relaxation for planned cholecystectomy, with TOF 0 achieved at 165.9 ± 95 seconds for Kruaron and 183.3 ± 90 seconds for Ridelat-C. In emergency abdominal surgery, it took 207.1 ± 120 seconds with Kruaron and 255.5 ± 109.5 seconds with Ridelat-C at TOF0. Notably, Kruaron exhibited prolonged effects in Group II, leading to residual neuromuscular block in critically ills even 2.5 hours post-surgery. *Conclusion.* Neuromuscular blocking agents modestly exacerbated neuromuscular dysfunction, potentially contributing to acquired critical illness polyneuropathy/myopathy, severe sepsis/septic shock, and massive blood loss/haemorrhagic shock. In critically ills, a minimal calculated dose of Kruaron is recommended, while Ridelat-C, which metabolized within the blood plasma without involving the kidneys or liver, might be a better choice. Suggamadex was suggested for reversing Kruaron effects due to its rapid effect as compared to proserine.

Keywords: neuro muscular block monitoring, planned cholecystectomy, emergency abdominal surgery, Kruaron, Ridelat-C, Residual NMB

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Author contributions. Dhunputh N. — research concept, data collection; Dhunputh N. — Analysis of data obtained; Dhunputh N., Petrova M, Butrov A. — entry of the data obtained, Analysis of data obtained; Dhunputh N., Moroz V., Dhunputh N., Magomedov M — text writing. Each author contributed personally to the interpretation of the data and writing the manuscript. All authors read and approved the final manuscript.

Conflict of interest statement. The authors declare no conflict of interest.

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Consent for publication. Written voluntary consent was obtained from the patients for the investigation and publication of relevant medical information according to WMA Declaration of Helsinki — Ethical Principles for Medical Research Involving Human Subjects, 2013.

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Introduction

Neuromuscular block anesthetics NMBA by definition are anesthetic drugs causing skeletal muscle paralysis initially by making a decrease response to acetylcholine at the neuro-muscular junction of skeletal muscle [1]. During surgery NMBA enhance endotracheal intubation by protecting patients from vocal cord injury thus improving the task of the surgeons by stopping involuntary reflex skeletal muscle movements [2]. Neuromuscular block in a sense after a surgery can be rapidly and effectively stopped. Seemingly, it was being identified that NMBAs proceed to act further in the post anesthesia care unit despite the administration of acetyl cholinesterase inhibitor. Residual neuro-muscular block is characterized by a bunch of muscle weakness in the post-operative period after NMBAs which is a matter of concern [3] Also, in critically ill patients, residual NMB is presently a very alarming problem in PACU unfortunately 60 % of the world's patients undergoing massive open abdominal emergency surgery have been reported with residual neuromuscular block [4–7] Many cases of residual neuromuscular block had been reported without the use of antidotes notably: «Proserine or Sugammadex» for their reversal [8]. For the betterment of the patient's health and to lose less time in operation theatre the proper monitoring of NMB using a train-of-four stimulation (TOF) Watch SX is a plus [9]. Massive blood loss, hypovolemia, severe sepsis, peritonitis, pancreatic necrosis, dysfunction of liver or kidneys are the underlying pathologies affecting the time of action, duration, excretion and the speed of recovery of muscle relaxants in emergency patients.

Material and Methods

140 patients undergoing planned laparoscopic cholecystectomy and emergency abdominal surgeries notably (laparotomy appendectomy, resection of a part of the intestines, relaparotomy, lavage and drainage of the abdominal cavity, pancreatectomy, endoscopic suturing of internal GIT bleeding organs, laparoscopic pyloroplasty) whereby TOF watch SX Organon (Dublin Ireland Serial no.14–2007058) was used for monitoring the depth of muscle relaxant.

Kruaron the generic of rocuronium bromide (Verofarm OOO, Harabovsk, Russia) and Ridelat-C the generic of atracurium benzilate (Sotex, Deco company, Moscow, Russia) were intravenously administered. Proserine was also used as antidote together with the mechanical ventilation apparatus-Drager Fabius. Written voluntary consent was obtained from the patients for the investigation and publication of relevant medical information according to WMA Declaration of Helsinki — Ethical Principles for Medical Research Involving Human Subjects, 2013.

Inclusion Criteria:

— adult male and female patients aged 18 to 60;
— planned for a patient surgical intervention of medium duration (60–90mins);
— the severity of the condition before surgery according to the ASA classification (American Society of Anesthesiologists) — ASA Class I–IV;
— patients with body mass index $18 < BMI < 30$ kg/m^2; Patients who have agreed to participate in the study, have read the patient information sheet and signed the informed consent of the Patient, and are willing to cooperate in the course of the study;
— patients who are scheduled to undergo surgery using total intravenous anesthesia or combined endotracheal anesthesia (propofol, fentanyl, midazolam, etc.) with an estimated duration of surgery of 30–120 minutes.

Exclusion Criteria:

— patients with significant disorders of neuro-muscular conduction, neuromuscular diseases (including myasthenia gravis, Eaton-Lambert syndrome, a history of poliomyelitis, etc.);
— use in the perioperative period of drugs related to prohibited therapy in the study;
— patients who have contraindications to the use of the TOF Watch device (including Pacemaker, etc.).
— patients with II–IV-degree burns;
— patients with a history of hypersensitivity to drugs of the class used (atracurium benzilate, rocuronium bromide, cisatracurium benzilate, pancuronium bromide, vecuronium bromide etc.);
— patients with burdened allergic history (serious systemic manifestations of allergic reactions in history);
— patients who participated in other clinical studies within the last 6 months. or currently participating in other clinical trials;
— any other disease or condition that, in the opinion of the investigator, may confound the results of the study.

Methods to implement

1. Determine the effect of muscle relaxants (aminosteroid and benzylisoquinoline composition) on neuromuscular conduction including emergency abdominal surgeries using TOF watch sx.

2. Intravenous administration of Kruaron «rocuronium bromide», Ridelat-C «atracurium benzilate» in planned cholecystectomy (research-group1) and in emergency abdominal surgery by conducting a study according to the following criteria: TOF 0, TOF 25 %, TOF 75 % and TOF 90 %

3. After administration of the 1st dose and compile statistics on the result obtained with atracurium benzilate and rocuronium bromide in emergency abdominal surgery (research group2) to see how they differ from laparoscopic cholecystectomy (control group1)

4. Proserine was given for reversal and the time of reversal of Kruaron and Ridelat-C were analysed.

A research work was being carried out on 140 patients in the City Clinical Hospital named after V.V. Vinogradova of the Moscow Healthcare Department» (City Clinical Hospital No.64 of Moscow Department of Healthcare), Russia to assess the variability of muscle relaxants during emergency abdominal surgery in comparison to planned cholecystectomy (the control group). They were being classified into two different groups; the first group of patients n = 61 (group 1) who underwent planned laparoscopic cholecystectomy and the other group n = 79 (group 2) who underwent emergency abdominal surgeries notably patients with such diagnosis: pancreatitis/pancreanecrosis, peritonitis, severe blood loss and sepsis.

The TOF –reading demonstrates four levels of blockade:

1.Complete blockade
2. Deep blockade
3. Moderate blockade
4. Phase of recovery of NMB

Immediately, after IV administration of muscle relaxant on induction for endotracheal intubation, the TOF watch SX was switched on, at 50mA a small electrical current generated by the later stimulates the ulnar nerve at the site of the connected anode and cathode to create a slight «twitch» a movement of the thumb where a result was reflected on the screen of the TOF watch. The time for the TOF watch to show zero representing complete muscle relaxation after iv administration of a first dose of muscle relaxant is recorded and further TOF results like 25 %, 75 % and 90 % were recorded. From 60 to 89 % it represents that the effect of muscle relaxant is slowly fading away and from 90 % –100 % it means that the patient can be extubated. The time was meticulously recorded in accordance to the results presented by the TOF watch sx (Fig. 1, 2).

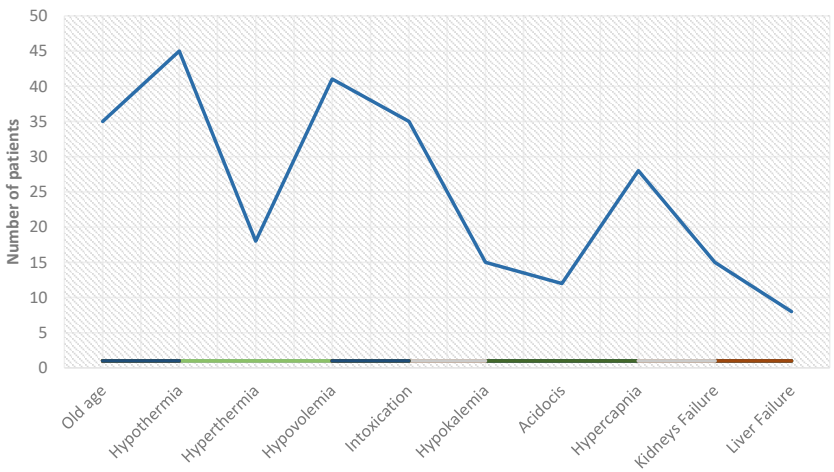

Fig. 1. The effects of different factors on muscle relaxants administered to the patients

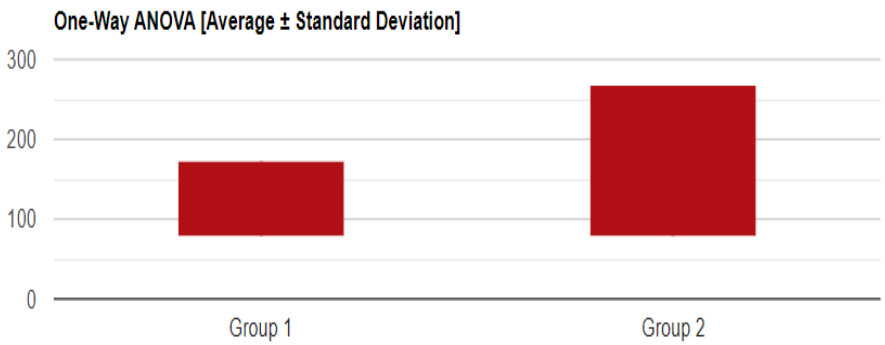

Fig. 2. A comparison of train-of-four stimulation (TOF) 0/sec results of group 1 and 2 patients after administration of an additional supporting dose of Ridelat-C (*p*-value = 0.036) by ANOVA

Statistical analysis

The statistical analysis of the results was processed in the one-way analysis of variance calculator ANOVA followed by Bonferroni post-hoc tests to determine significance. Differences were considered statistically significant when p value was less than 0.05 ($p < 0.05$), protocol of pre-surgical patient's examination, protocol of combined endotracheal anesthesia, protocol of clinical research, laboratory results, control group1 laparoscopic cholecystectomy [10] and research group emergency abdominal surgery group 2 were used.

Results and Discussion

The selection of the proper muscle relaxant and dosage for induction in emergency abdominal surgery patients was needed. Kruaron, the generic form of rocuronium bromide an amino steroid drug by definition is a rapid acting non- depolarizing intermediate muscle relaxant having all pharmacological effects characteristic of this class of drugs. It is concurrently blocking N-cholino receptors of the end plate motor neurone. At a dose of 0.60mg/kg for intubation it takes 60seconds to total relaxation of skeletal muscle that is TOF 0. Its clinical duration 0.60 mg/kg is 30 to 40mins at TOF 25 % and around 50mins at TOF 90 %. The middle duration between TOF 25 % to TOF 75 % is 14mins. For a small dose of 0.30–0.45 mg/kg for intubation, it takes 90seconds to reach TOF 0 (very deep muscle relaxation). In relation to the pharmacokinetics, after bolus IV administration of a starting dose its plasmatic concentration undergo through three exponential phases. For healthy adults its half-length of elimination is 66–80mins and its clearances through plasma is estimated to be 3.5–3.9 ml/kg/min. Kruaron is eliminated from the human body through urine or bile.

The tables 1–3 show how the two muscle relaxants varied for the planned cholecystectomy and emergency abdominal surgeries registered throughout the research work.

Table 1

Control group I and emergency group II using Kruaron and Ridelat-C for a first intubating dose

Types of surgeries	Group I		Group II	
First intubating Dose	Kruaron R 0.5 mg/kg N = 17	Ridelat C 0.5 mg/kg N = 16	Kruaron R 0.5 mg/kg N = 15	Ridelat C 0.5 mg/kg N = 23
TOF 0	165.9 ± 95	183.3 ± 90	207.1 ± 120	255.5 ± 109.5
TOF 25 %	43.7 ± 9.2	47.3 ± 9.4	37.7 ± 8.2	47.6 ± 12.4
TOF 75 %	64.5 ± 13	63.7 ± 13.1	69.4 ± 23.1	66.5 ± 15.1
TOF 90 %	75.6 ± 15.4	77.5 ± 10.3	94.1 ± 29.3	81.5 ± 16.1

Note: The time of action of Ridelat-C is more as compared to that of Kruaron at train-of-four stimulation (TOF) 0/secs for a first intubating dose.

Table 2

Control group I and emergency group II using Kruaron and Ridelat-C for a first intubating dose and an additional supporting dose

Types of surgeries	Group I		Group II	
First Intubating Dose	Kruaron R 0.5 mg/kg N = 15	Ridelat C 0.5 mg/kg N = 13	Kruaron R 0.5 mg/kg N = 22	Ridelat C 0.5 mg/kg N = 19
TOF 0	194.6 ± 132	175.3 ± 96	327.9 ± 193.8	296.8 ± 108.5
TOF 25 %	34.8 ± 10.7	37.2 ± 14.8	38.3 ± 11.9	35 ± 10.3
Additional Supporting dose	0.2 mg/kg	0.2mg/kg	0.2mg/kg	0.2mg/kg
TOF 0	184 ± 97	126.6 ± 46	141 ± 59.5	173.1 ± 93.5
TOF 25 %	43.8 ± 12.3	32.9 ± 15.5	35.6 ± 15.5	35.4 ± 10.2
TOF 75 %	62.2 ± 14.5	43.2 ± 17.6	59.9 ± 30.9	51.6 ± 12.2
TOF 90 %	74 ± 17.3	51.6 ± 18.4	79.9 ± 30.4	60 ± 13.1

Note: The time of action of Ridelat-C is more as compared to that of Kruaron at train-of-four stimulation (TOF) 0/secs for a first intubating dose and an additional supporting dose at TOF0/secs and higher as compared to Table 1.

Table 3

Groups I and II extubation with proserine

Surgeries	Planned Laparoscopic Cholecystectomy Group I		Emergency Abdominal Surgery Group II	
Muscle relaxants/N	Kruaron N = 5	Ridelat-C N = 7	Kruaron N = 5	Ridelat-C N = 6
TOF 90 % with Proserine/min	3 ± 0.8	4 ± 2.9	6 ± 4.5	3 ± 1.6
Extubation with Proserine/min	65	117.6	72	79.2
Extubation without Proserine/min	73	122	88.2	100.3

Note: For group II patients more time is taken for Kruaron to be reversed by proserine.

Basically, during the course of the research work being carried out in anesthesiological block where planned laparoscopic cholecystectomy (control group) and emergency abdominal surgeries (experimental group) where the TOF watch SX showed that for planned cholecystectomy of Kruaron on induction at a first intubating dose of 0.50 mg/kg for TOF to reach zero it took 165.9 ± 95 seconds and for emergency abdominal surgery it took 207.1 ± 120 secs (Table 2). Structural differences for cases of first administration of Kruaron to adults aged 18–60 for TOF readings in minutes showing the variation in percentage are represented on figure 3.

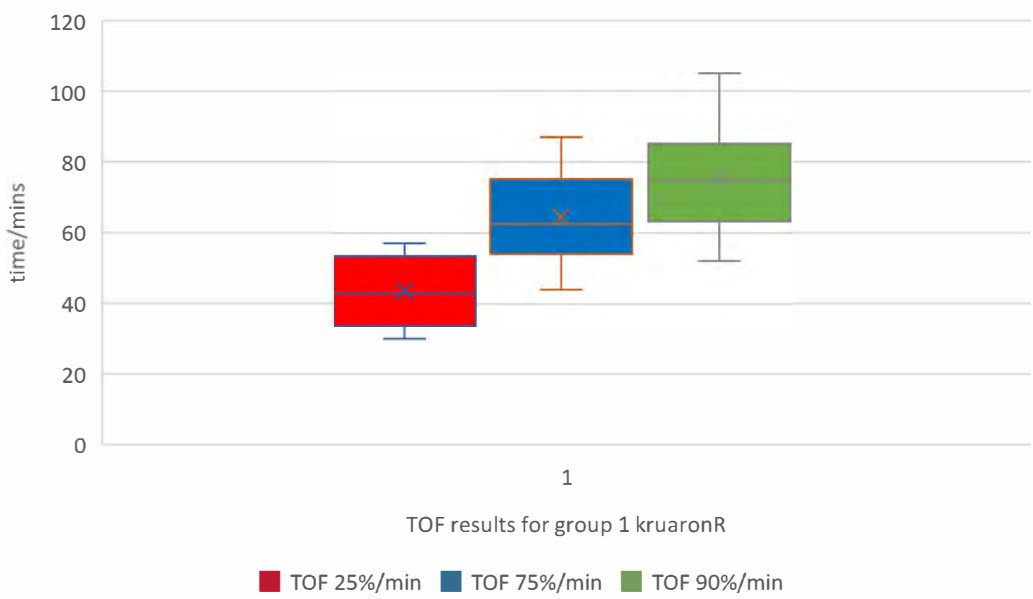

Fig. 3. Structural differences for cases of first administration of Kruaron to adults aged 18–60 for TOF readings in minutes showing the variation in percentage; TOF- train-of-four stimulation

It was problematic for the anesthesiologist because it took longer time to reach TOF 0 and the fact that he had to intubate the patient and the latter was not fully relaxed is highly disturbing. Many incidences of vocal cord injury were registered on intubation. Intra operation and post-surgery during both planned and emergency surgeries all patients were viewed with hypothermia of a body temperature of 34 ± 0.5 degrees celsius. Mostly on elderly patients aged 65 and above, residual NMB with Kruaron was recorded three hours post-surgery for emergency abdominal surgery patients with sepsis, hypovolemia and massive blood loss TOF showed 50–55 % (Fig. 4).

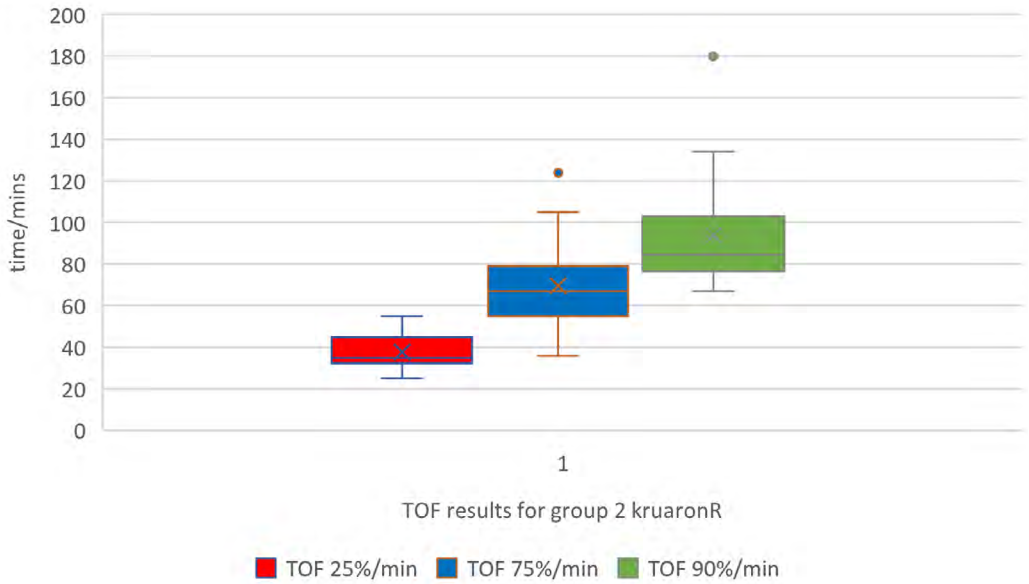

Fig. 4. Structural differences for cases of first administration of Kruaron to adults aged 18–60 for TOF readings in minutes showing the variation in percentage for emergency abdominal surgery, TOF- train-of-four stimulation.

The duration of planned laparoscopic cholecystectomy is one hour and that of emergency abdominal surgery is from 2.5 to 3 hours respectively. For extubation on many instances proserine was used to reverse Kruaron however for emergency patients' reversal was attained at 6 ± 4.5 mins and planned surgery patients at 3 ± 0.8 mins (refer to Table 4). Most of the time during emergency abdominal surgeries extubation cannot be performed because of residual Kruaron in the patient's body hence the later did not react to any stimuli notably: holding the doctor's wrist firmly, extending his head up, confirming whether the intubation tube is disturbing him; and had to be transferred to ICU for prolonged mechanical ventilation support [11]. It is being debated whether or not for emergency abdominal surgeries on critically ill patients with sepsis, kidneys /liver dysfunction, hypovolemic, massive bleeding whether Kruaron is reliable to use or not. Furthermore, if we used Ridelat-C to stop residual NMB this will ease the work of the anesthesiologist in surgical block and extubation also will be quicker without the use of any reversal antidote. Ridelat-C is the generic of atracurium benzilate a non- depolarizing muscle relaxant with peripheral action. It reduces the sensitivity of skeletal muscle N cholinergic receptors to acetylcholine, inhibiting neuromuscular trans-mission and causing transient skeletal muscle relaxation. It has a rapid onset of action of 2–2.5 minutes, allowing for endotracheal intubation in 90 seconds at an initial dose of 0.5–0.6 mg/kg. At TOF 95 percent, spontaneous recovery after a beginning dose of 0.2–0.6 mg/kg takes about 20–35 minutes. In blood plasma, it takes 1.7–10 minutes to attain plasma Cmax. The duration of the neuromuscular blocking activity is unaffected by the degree of hepatic metabolism or the pace of kidney excretion. It decomposes at physiological blood pH and body temperature without the involvement of enzymes it is hydrolyzed to a limited extent to butyrylcholinesterese (Hoffman elimination) to laudanosine and quaternary mono-acrylate, thus the duration of action is not dependent on the kidneys or the liver. Pharmacologically, metabolites are inactive. The duration of action is unaffected by physiological variations in blood pH. The rate of inactivation slows down under hypothermia (25–26 degrees Celsius). It does not build up in the body and does not reach clinically significant amounts through the placental barrier. T1/2 is 20 minutes and half-life are 2–3.4 minutes. The kidneys and the intestines excrete Ridelat-C.

In planned laparoscopic cholecystectomy for TOF to be zero Ridelat-C took 183.3 ± 90 secs Table2 which was normal at a dose of 0.4 mg/kg and for emergency abdominal surgery 255.5 ± 109.5 secs (Table 2). A recovery period for planned cholecystectomy patients at TOF 90 % was recorded at 77.5 ± 10.3 mins (Table 2) and with a maintenance dose of 0.20mg/kg where TOF 90 % was recorded at 51.6 ± 18.4 mins (Table 3). For patients undergoing emergency abdominal surgery TOF 90 % was recorded at 81.5 ± 16.1 (Table 2, Fig. 5, 6).

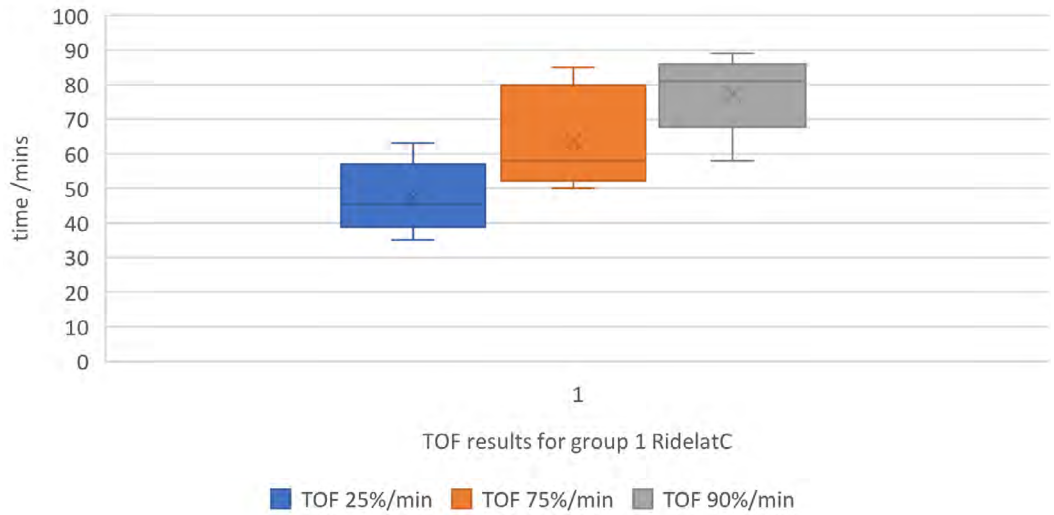

Fig. 5. Structural differences for cases of first administration of Ridelat-C to adults aged 18–60 for TOF readings in minutes for the variation in percentage, TOF- train-of-four stimulation

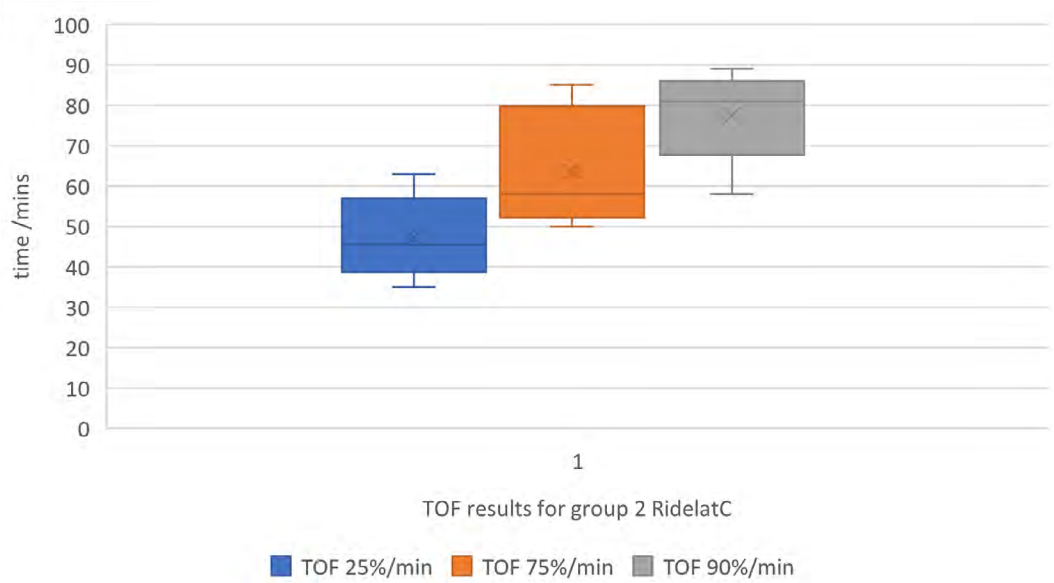

Fig. 6. Structural differences for cases of first administration of Ridelat-C to adults aged 18–60 for TOF readings in minutes showing the variation in percentage for emergency abdominal surgery, TOF- train-of-four stimulation

With a maintenance dose of 0.20mg/kg the recovery time at TOF 90 % was 60 ± 13.1 mins (Table 3). A standard dose can be administered to patients with end stage renal failure or end stage liver failure. Most appropriately Ridelat-C is considered to be more appropriate to use for critically ill emergency abdominal surgery patients with sepsis and massive blood loss, renal and liver failure as compared to Kruaron which has residual NMB effect which is detrimental to human health.

The effect of different drugs, physical and metabolic factors during myoplegy intravenous anesthetics Amaki Y. and co- authors described that on research on mouses where ketamine was administered, not only increased the effect of MR but also increased the presynaptic excretion of acetylcholine. During total intravenous anesthesia whereby propofol was used in a time interval more than 20 mins it was estimated that propofol can prolong the duration of non-depolarizing MR Hemmerling T.M. et al, they acted on the central and peripheral hemodynamics changing the pharmacodynamics of MR.

Inhalational anesthetics

Desflurane and sevoflurane enter the synapse quickly because they are less soluble in blood and tissues than other volatile anesthetics supported by Yasuda N. et al. [12]. Non-depolarizing MR's effect is amplified by inhalation anesthesia; as a result, during anesthesia, the frequency and dose of MR are reduced in order to maintain NMConduction, and the duration and recovery time of NMB are extended Cannon J.E., et al.; Saitoh K. et al.; Suzuki T., et al. Desflurane>Sevoflurane> Isoflurane> Halothane> Nitrous Oxide> Barbiturates>Opioids >Propofol> Ketamine are all anesthetics, including intravenous ones, in order of the degree of NMB potentiation. Among others, in the presence of inhalation anesthetics, it is advised to reduce the maintenance dose of muscle relaxant by 20 % of the main dose [13].

Local anesthetics

Despite the sparseness of parenterally administered local anesthetic (LA) overdoses in clinical practice, anesthesiologists must be aware of how LA might alter the pre and postsynaptic regions of the neuromuscular conduction as well as the activity of the muscle cell. When LA is administered intravenously at doses that are significantly beyond therapeutic levels, neuromuscular conduction without MR is clinically inhibited, and depolarizing and non-depolarizing NM conduction are both boosted at standard doses [14].

Antibiotics

In the absence of MR, most antibiotics are able to inhibit NMC. Antibiotics have a noticeably more significant myoplegic impact when MR is present. For example, aminoglycosides, polymyxins and lincosamides given parenterally in the pre and intraoperative period inhibit the presynaptic release of ACh, lower the sensitivity of receptors to ACh, thereby prolonging the action of MR for many hours [15]. When combined with MR, tetracycline medications enhance NMB, which is then removed by AChP Lee C. et al. Tetracycline medications only have a postsynaptic effect. An antibiotic injected into the pleural and abdominal cavities and then absorbed into the systemic circulation can have a clinically significant myoplegic impact.

Intake of electrolytes

Magnesium sulfate prolongs NMC therefore the dosage of MR has to be minimum [16]. According to certain findings, magnesium sulfate at a dose of 60, 90 mg/kg can function as an antagonist of succinylcholine. If hypercalcemia (2–3 mmol/l) is not treated before surgery, it may be possible to shorten NMB while necessitating more MR. There is an expansion of both depolarizing and non-depolarizing NMC in patients receiving pre- and intraoperative lithium preparations, primarily for mental illness [17].

Other medications

The quinidine series of antiarrhythmic medications work at the level of presynaptic transmission, extending non-depolarizing NMB [18].Tamoxifen and other anti-estrogen medications have been shown to enhance the effects of non-depolarizing. Mannitol, an osmotic diuretic, has no impact on the depth or

duration of NMB. The strength and duration of both depolarizing and non-depolarizing NMB are increased when furosemide is administered intravenously to individuals with renal impairment at a dose of 1 mg/kg Azar I. et al. Long-term anticonvulsant medication may cause patients to become resistant to non-depolarizing MR, whereas depolarizing MR may cause depolarizing hyper-sensitivity. Prednisolone, dexamethasone, and other steroid medications reduce non-depolarizing MR's effects on people [19]. It is further supported by T. Magorian, K.B. Flanerry et al. that succinylcholine may be replaced by rocuronium, a brand-new nondepolarizing muscle relaxant with a fast onset of action but no side effects come with succinylcholine [20]. The authors compared rocuronium, succinylcholine, and vecuronium for rapid sequence anesthetic induction in order to evaluate this theory.

Patients undergoing neurosurgery, aortic surgery, or procedures involving motor-evoked potential (MEP) monitoring face the risk of postoperative mobility issues due to surgical damage. To secure endotracheal tubes during general anesthesia, muscle relaxants like rocuronium are often used but can significantly reduce MEP. Therefore, caution is needed when using muscle relaxants during MEP-monitored procedures.

In Japanese patients undergoing spine surgery, a study explored the impact of neuromuscular blockade (NMB) on MEP [21–23]. The research included adults receiving propofol/remifentanil anesthesia, rocuronium for intubation, and myogenic MEP monitoring after transcranial stimulation. Sugammadex was administered when MEP configuration was complete, achieving a TOF ratio of 0.7. Factors influencing the TOF ratio included age, blood pressure, hepatic impairment, and rocuronium dose. Higher TOF ratios (0.75) correlated with improved MEP detection success rates.

Out of 373 cases, 221 (59.2 %) received sugammadex. Sugammadex treated patients had a significantly shorter interval between NMB recovery and the start of MEP monitoring compared to control patients ($P < 0.0001$). Patients with a TOF ratio closer to 1 had a higher success rate in MEP detection.

Conclusion

The dosage of Kruaron in emergency abdominal surgery, especially for critically ill patients, required reconsideration due to significant delays in achieving complete muscle relaxation for combined endotracheal anesthesia. It was suggested that an additional dose of 0.1–0.2 mg/kg might be necessary in such cases. Critically ill patients transported to the intensive care unit immediately after emergency abdominal surgery showed residual neuromuscular block with a TOF result of ≤ 60 % 2.5 hours later.

Kruaron's elimination was reduced in patients with sepsis, hypovolemic shock, and massive blood loss, either through urine or bile. In contrast, Ridelat-C proved to be effective for endotracheal intubation in patients with sepsis, peritonitis, or massive blood loss due to its elimination mechanism and less of physical counter reactions, it did not depend on the liver of the kidneys to be excreted. However, a calculated dose of Kruaron was needed for patients with stomach regurgitation. Ridelat-C's duration was shorter by 30–35 minutes compared to Kruaron and was quickly eliminated from the body at a TOF 90 %-95 %.

Proserine was used to facilitate extubation and reverse neuromuscular blockade. Reversal of Ridelat-C was significantly faster than Kruaron. Group 2 patients required more time for proserine to be neutralized compared to group 1 patients.

Re-evaluation of a lesser appropriate dosage of Kruaron was essential for group 2 emergency abdominal surgery patients. Also, factors like high temperatures, hormonal drugs (e.g. prednisolone), smoking, obesity, and circadian time with melatonin, could affect the efficacy and duration of muscle relaxants.

This study highlighted the modest connection between neuromuscular blocking agents and neuromuscular dysfunction, as well as their association with acquired critical illness polyneuropathy/myopathy, severe sepsis/septic shock, and massive blood loss/hemorrhagic shock. For emergency critically ill patients, administering a minimal calculated dose of Kruaron or opting for Ridelat-C appeared to be a safer choice. To expedite extubation and save operation time, sugammadex should be used for Kruaron reversal,

given the delayed action of proserine. A new protocol of combined endotracheal intubation for critically ill patients should be introduced.

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Мониторинг нейро-мышечного блока при экстренной абдоминальной хирургии

Н. Данпут ✉, М.В. Петрова, В.В. Мороз, А.В. Бутров, М.Ф. Магомедов

Российский университет дружбы народов, г. Москва, *Российская Федерация*
✉ dhunputhneelam@gmail.com

Аннотация. *Актуальность*. Во всем мире зарегистрировано около шестидесяти процентов случаев остаточной нервно-мышечной блокады (рНМБ), но вопрос о рНМБ у пациентов в критическом состоянии остается не исследованным. Для прогнозирования наличия остаточного НМБ использовался TOF Watch SX для определения глубины введения миорелаксанта у пациентов, нуждающихся в экстренном хирургическом вмешательстве во время и после операции, даже когда они были транспортированы в отделение интенсивной терапии. *Цель* данного исследования состояла в том, чтобы сравнить варианты нервно-мышечной блокады между плановой лапароскопической холецистэктомией и экстренной абдоминальной хирургией. В исследовании приняли участие 140 пациентов в возрасте 18–60 лет с ИМТ 18–30 кг/м². В I группе была выполнена плановая холецистэктомия (контрольная группа), во II группе — экстренная абдоминальная хирургия (исследовательская группа). Глубину миорелаксации контролировали с помощью часов TOF SX. Назначались два миорелаксанта: Риделат-С, атракурия безилат (Сотекс, компания «Деко», Москва, Россия) и Круарон, рокурония бромид (Верофарм ООО, Харабовск, Россия). Были использованы различные методы, в том числе Drager Fabius, протокол пред-анестезии, протокол исследования, протокол комбинированной эндотрахеальной анестезии, мониторинг динамики, ЭКГ, результаты лабораторных исследований, Microsoft Excel Advanced, ANOVA. *Результаты и обсуждение.* Результаты продемонстрировали глубокую релаксацию скелетных мышц при плановой холецистэктомии: TOF 0 достигался за 165,9 ± 95 секунд для Kruaron и 183,3 ± 90 секунд для Ridelat-C. При экстреной абдоминальной хирургии это заняло 207,1 ± 120 секунд для Kruaron и 255,5 ± 109,5 секунд для Ridelat-C при TOF0. Примечательно, что Круарон® продемонстрировал пролонгированное действие в группе II, приводя к остаточному нервно-мышечному блоку у больных в критическом состоянии даже через 2,5 часа после операции. *Выводы. Н*ервно-мышечные блокаторы умеренно усугубляют нервно-мышечную дисфункцию, потенциально способствуя приобретенным критическим заболеваниям: полиневропатии/миопатии, тяжелому сепсису/септическому шоку и массивной кровопотере/геморрагическому шоку. Для критических больных рекомендуется минимальная расчетная доза Круарон®, тогда как Риделат С, который метаболизируется в плазме крови, не затрагивая почки или печень, может быть лучшим выбором. Суггамадекс был предложен для устранения эффектов Круарон® из-за его быстрого эффекта по сравнению с прозерином.

Ключевые слова: мониторинг нейромышечного блока, плановая холецистэктомия, экстренная абдоминальная хирургия, Круарон, Риделат-С, остаточный нейро-мышечный блок.

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Corresponding author: Neelam Dhunputh — PhD student of the Department of Anesthesiology and Reanimatology with the course of rehabilitology, Institute of Medicine, RUDN University, 117198, Miklukho- Maklaya str., 6, Moscow, Russian Federation. E-mail: dhunputhneelam@gmail.com
Dhunputh N. ORCID 0009–0004–7058–5021
Petrova M.V.ORCID 0000–0003–4272–0957
Moros V.V. ORCID 0000–0002–3467–7170
Butorov A.V. ORCID 0000–0003–4462–1530
Magomedov M.A. ORCID 0000–0002–1972–7336

Ответственный за переписку: Данпут Нилам — аспирант кафедры анестезиологии и реаниматологии с курсом медицинской реабилитации, медицинский институт РУДН, Российская Федерация, 117198, г. Москва, ул. Миклухо-Маклая, д. 6. E-mail: dhunputhneelam@gmail.com
Данпут Н. ORCID 0009–0004–7058–5021
Петрова М.В. ORCID 0000–0003–4272–0957
Мороз В.В. ORCID 0000–0002–3467–7170
Бутров А.В. ORCID 0000–0003–4462–1530
Магомедов М.А. ORCID 0000–0002–1972–7336