e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(6); 33-38

Original Research Article

Comparison of Sugammadex and Neostigmine/Glycopyrrolate in Reversing Neuromuscular Blockade in Adults Using Neuromuscular Monitor

Kallol Ganguly[1], Prithviraj Chakraverty[2], Subhashis Saha[3], Debjani Gupta[4]

[1]Postgraduate Trainee, Department of Anaesthesiology, KPC Medical College & Hospital, Jadavpur, Kolkata, West Bengal, India

[2]Assistant Professor, Department of Anaesthesiology, KPC Medical College & Hospital, Jadavpur, Kolkata, West Bengal, India

[3]Senior Resident, Department of Anaesthesiology, KPC Medical College & Hospital, Jadavpur, Kolkata, West Bengal, India

[4]Associate Professor, Department of Anaesthesiology, KPC Medical College & Hospital, Jadavpur, Kolkata, West Bengal, India

Received: 01-03-2026 / Revised: 15-04-2026 / Accepted: 21-05-2026

Corresponding author: Dr. Subhashis Saha

Conflict of interest: Nil

Abstract

Background: Neostigmine, the conventional agent for neuromuscular blockade reversal, acts indirectly by inhibiting acetylcholinesterase and is associated with unpredictable recovery times and muscarinic side effects. Sugammadex, a modified γ-cyclodextrin, reverses steroidal neuromuscular blocking agents by direct encapsulation, offering the potential for rapid and predictable reversal. While prior studies demonstrated its efficacy in deep blockade, evidence comparing both agents in moderate blockade under inhalational anaesthesia was limited.

Methods: One hundred twenty patients, of either sex, ASA physical status I or II, undergoing elective Laparoscopic cholecystectomy under general anaesthesia, were randomly allocated into two groups containing sixty patients each. Group A received Sugammadex for Reversal of muscle relaxant and Group B received Neostigmine/Glycopyrrolate for Reversal of Muscle Relaxant.

Results: Sugammadex achieved TOF ≥ 0.9 significantly faster than Neostigmine (89 second versus 399 second, $P < 0.0001$). 98% of patients receiving Sugammadex recovered within 2 minutes showing greater predictability, while with neostigmine some patients required more than 7 minutes to recover.

Conclusion: Sugammadex provides markedly faster, more predictable, and reliable reversal of moderate rocuronium-induced neuromuscular blockade compared with neostigmine during sevoflurane anaesthesia, with a comparable safety profile.

Keywords: Sugammadex, Neostigmine, Neuromuscular Blockade, Neuromuscular Monitor.

DOI: 10.25258/ijcpr.18.6.7

Introduction

Neuromuscular blocking agents are an important component of modern anaesthetic practice to improve surgical conditions by suppression of voluntary or reflex muscle movements. After surgery, reversal agents such as neostigmine or pyridostigmine are commonly administered to accelerate the recovery of neuromuscular function. Unfortunately, these drugs neither provide predictable nor sufficiently fast restoration of neuromuscular function [1] and may be associated with several side effects, related to the inhibition of cholinesterase activity [2].

Sugammadex is a modified γ-cyclodextrin specifically developed for rapid reversal of a rocuronium-induced or vecuronium-induced neuromuscular blockade by forming a stable and inactive complex with these neuromuscular blocking agents [3]. Dose-calculating studies have shown specific doses of sugammadex that rapidly reverse specific degrees of neuromuscular blockade after rocuronium [4]. A phase 3 active-controlled, randomised study proved that sugammadex provides significantly faster reversal of a deep rocuronium induced neuromuscular blockade compared with neostigmine [5].

Rapid, complete, and reliable reversal of neuromuscular blockade is desirable to improve patient comfort and safety. To achieve this goal, there is general agreement that return to a train-of-four (TOF) ratio of 0.9 or greater should be achieved at the end of surgery before extubation. Despite intraoperative use of nerve stimulation to gauge depth of blockade and adequacy of reversal with acetylcholinesterase inhibitors, many patients do not achieve adequate neuromuscular recovery before tracheal extubation in the early postoperative period [6]. The occurrence of postoperative residual neuromuscular blockade in the recovery room may result in airway obstruction, pulmonary complications, and other significant morbidity [7,8].

The administration of acetylcholinesterase inhibitors (Like - neostigmine, edrophonium) can lead to cardiovascular, gastrointestinal, and respiratory adverse events (AEs) through undesired stimulation of muscarinic receptors, [9,10] resulting in the need for co-administration of muscarinic antagonists such as glycopyrrolate or atropine. These agents may themselves induce adverse events (AEs) such as tachycardia, blurred vision, and sedation [11].

In current clinical practice, however, reversal of neuromuscular blockade ideally takes place after return of the train-of-four (TOF) response to one or two twitches (T1 or T2), which is at a moderate level of blockade. In a placebo-controlled, dose calculating study, sugammadex at doses of 2 mg/kg or greater administered at reappearance of T2 following a single dose of rocuronium allowed recovery to a TOF ratio of 0.9 in a median of less than 2 min.

A Cochrane review on Sugammadex concluded that Sugammadex was shown to be more effective than placebo (no medication) or neostigmine in reversing muscle relaxation caused by neuromuscular blockade during surgery and is relatively safe. Serious complications occurred in less than 1% of the patients who received Sugammadex. This study aims to corroborate the same.

Materials and Methods

This was a randomized, comparative interventional clinical study performed in KPC Medical College and Hospital, Jadavpur from June 2024 till November 2024. After getting approval from the institutional ethical committee, and CTRI registration (CTRI/2024/05/067883), an informed consent was taken from every patient enrolled in the study.

One hundred twenty patients aged ⩾18–⩽60 years, ASA physical status I and II, planned for elective laparoscopic cholecystectomy were included. The exclusion criteria included the following: Age less than 18 years and more than 60 years, ASA III/IV, known allergy to anaesthetic agents, history of substance abuse and current opioid use, pregnancy and unwilling patients.

Method of randomization:- Patients were allocated randomly by a computer-generated list of random permutations to one of two equal groups (60 patients each): group S and group N.

Group S – 60 patients were given intravenous inj. Sugammadex at appropriate dose (e.g., 2 mg/kg IV) during reversal.

Group O – 60 patients were given intravenous inj. Neostigmine (50 mcg/kg IV) + Glycopyrrolate (10 mcg/kg IV) during reversal.

Preoperative Preparation: All patients were kept fasting as per standard guidelines. On arrival in the operating room, standard monitors including ECG, non-invasive blood pressure, pulse oximetry, and capnography were attached. Baseline vital parameters were recorded.

Neuromuscular Monitoring: Objective neuromuscular monitoring was established according to international consensus guidelines [14,15] before induction of anaesthesia using a peripheral nerve stimulator. Train-of-four (TOF) monitoring was performed by stimulating the ulnar nerve at the wrist and recording the response of the adductor pollicis muscle. Baseline TOF responses were documented prior to administration of any anaesthetic or neuromuscular blocking drug.

Induction of Anaesthesia: All patients were preoxygenated with 100% oxygen for 3 minutes.

General anaesthesia was induced with Intravenous induction agent (e.g., propofol 2–2.5 mg/kg) and Opioid analgesic (e.g., fentanyl 2 mcg/kg). After loss of consciousness, mask ventilation was initiated.

Administration of Neuromuscular Blocking Agent: Following confirmation of adequate mask ventilation, rocuronium (0.6 mg/kg IV) was administered to facilitate tracheal intubation.

Neuromuscular monitoring was continued, and intubation was performed when adequate neuromuscular blockade was achieved (disappearance of TOF response or TOF count = 0).

Maintenance of Anaesthesia: Anaesthesia was maintained using Oxygen, nitrous oxide, and sevoflurane (titrated to maintain adequate depth of anaesthesia), intermittent or continuous dosing of rocuronium as required, guided by TOF monitoring Intraoperative analgesia and ventilation were maintained as per standard institutional protocol.

Assessment of Neuromuscular Blockade: Neuromuscular function was continuously monitored intraoperatively using TOF stimulation.

Additional doses of rocuronium were administered only when TOF count reappeared, ensuring controlled depth of blockade.

Reversal of Neuromuscular Blockade: At the end of surgery, reversal of neuromuscular blockade was performed based on TOF monitoring:

When TOF count ≥2 (moderate blockade), patients were randomly allocated into two groups:

Group S (Sugammadex Group): Sugammadex administered at appropriate dose (e.g., 2 mg/kg IV)

Group N (Neostigmine + Glycopyrrolate Group): Neostigmine (50 mcg/kg IV) + Glycopyrrolate (10 mcg/kg IV)

Post-Reversal Monitoring: After administration of reversal agents, TOF ratio was monitored every 15–30 seconds, Time taken to achieve TOF ratio ≥0.9 was recorded and Extubation was performed only after adequate recovery (TOF ≥0.9) and clinical criteria were met.

Postoperative Observation: Patients were monitored in the postoperative recovery area for: Residual neuromuscular blockade, Respiratory complications and Hemodynamic stability.

Statistics: Data were analysed using Statistical Package for Social Sciences (SPSS) version 29 (International Business Machines SPSS Statistics Inc., Chicago, Illinois, USA) Mac software program. Descriptive analysis for patient demographics and intraoperative events was carried out by mean and standard deviation for quantitative variables, frequency and proportion for categorical variables. Keeping confidence interval 95%, appropriate statistical tools & technique were used to find the association between variables.

Sample size: Sample size was calculated with reference to the previous study [12,13]. Assuming a dropout rate of 5%, it was decided to include 60 patients in each group. So, total sample size was 120 with each group had 60 patients.

Results

A total of 120 patients between the age of 18- 57 years with ASA grade I or II who underwent laparoscopic cholecystectomy were recruited for the study after obtaining an informed consent from the patient. Patients were equally randomized into two groups. Group S consisted of 60 patients (42 females and 18 males) with a mean age of 35.1 years (18 years - 57 years), Mean weight of 58.5 kgs (41 kgs - 86 kgs), Mean height of 155.2 cm (147 cm - 170 cm).

While Group N also consisted of 60 patients (42 females and 18 males) with a mean age of 34.7 years (18 years - 54 years), Mean weight of 54.1 kgs (38 kg - 82 kg), Mean height of 155.6 cm (147 cm - 168 cm). There was no statistically significant difference in mean age (p=0.814), weight (p=0.057) height (p=0.725) between the two study groups.

Table 1:

	Group	N	Mean	Median	SD	P Value
Age (Years)	N	60	34.7	34	8.30	0.814
	S	60	35.1	33.5	9.46	

Table 2:

	Group	N	Mean	Median	SD	P Value
Weight (Kg)	N	60	54.1	52	13.3	0.057
	S	60	58.5	56	11.3	

Table 3:

	Group	N	Mean	Median	SD	P Value
Height (cm)	N	60	156	153	5.60	0.725
	S	60	155	153	5.27	

Before giving any drugs for general anaesthesia Train of Four (TOF) value was taken for all patients. It was 1 for all patients.

After intubation Train of Four (TOF) value was taken and it was 0 for all patients. Muscle relaxant is giving monitoring the Train of Four (TOF) value. At the end of the surgery, when Train of Four (TOF) value is 2/4 or 0.5 reversal is given for every patient. Then Train of Four (TOF) value was monitored and recorded in every 15 sec up to 8mins or 480 sec.

Another data was taken 1 hr after giving reversal to see that the patient is fully reversed from muscle relaxant. Time taken for every patient from giving reversal to Train of Four (TOF) value >0.9 was calculated and recorded.

Table 4:

	Group	N	Mean	Median	Sd	P Value
Time Interval from Giving Reversal To TOF>0.9(sec)	N	60	399	390	23.2	<0.001
	S	60	89	90	11.3	

So, it can be seen that there is statistically significant difference between group N and group S at the time of reversal.

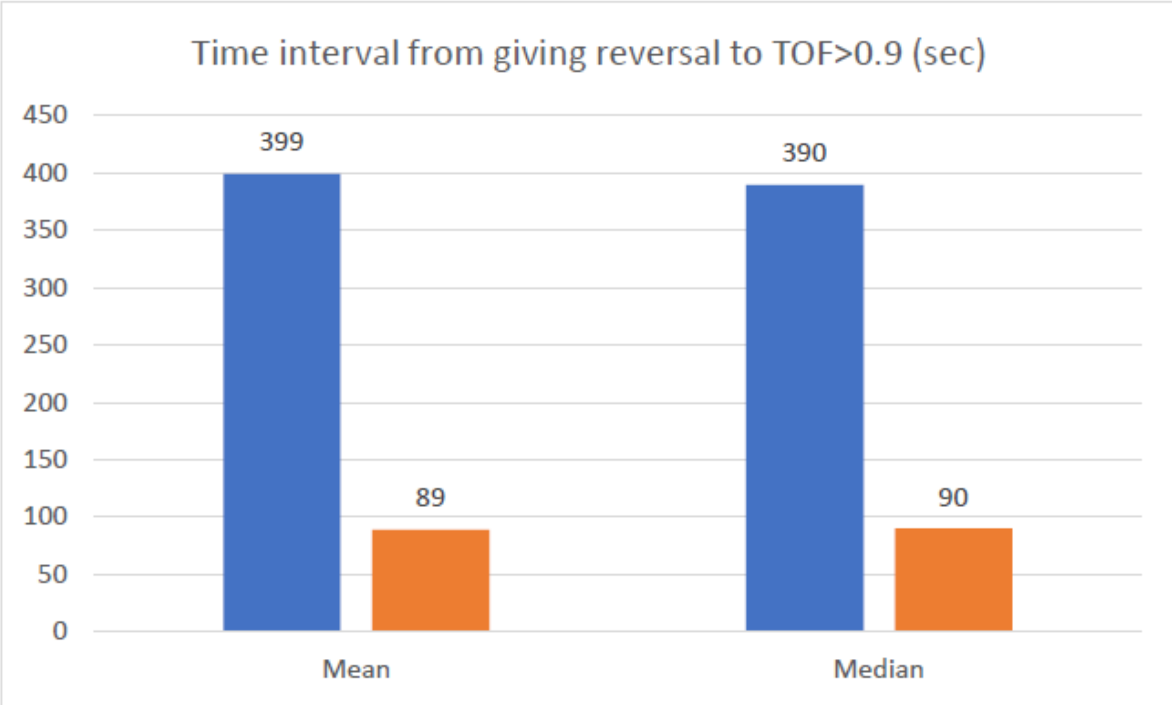

Figure 1: Time interval form giving reversal to TOF > 0.9 (sec)

Discussion

This study is the randomised, prospective, controlled study comparing the reversal properties of sugammadex with those of neostigmine, when used to reverse a moderate rocuronium-induced neuromuscular blockade in patients under sevoflurane anaesthesia. We show that 2.0 mg/kg sugammadex achieved significantly faster recovery to a TOF ratio of 0.9 compared with 50 mcg/kg neostigmine, when administered at recovery of T2 in the TOF response.

In addition, following reversal with sugammadex, we found lower variability of the recovery times. This resulted in 98% of patients recovering to a TOF ratio of 0.9 within 100 sec after sugammadex and after nearly 400 secs after neostigmine and glycopyrrolate. Neostigmine is currently the most widely used reversal agent in clinical practice. When administered at T1/T0 is equal to 10%, neostigmine in doses of 35–70 mcg/kg neuromuscular recovery to TOF values of 0.7 or 0.8 within approximately 10 min. In the current study, neostigmine was injected at reappearance of T2, a level at which mean T1/T0 was 16%. Geometric mean recovery times to TOF 0.9 was 399 sec, confirming the results of a previous neostigmine study for reversal of a rocuronium-induced neuromuscular blockade under sevoflurane anaesthesia. [13] The recovery times to TOF 0.9, however, were significantly prolonged (median 390 sec) and their large variability implied that, in many patients, neuromuscular function was not reversed within an acceptable time. Neostigmine does not pharmacologically antagonise muscle relaxants, but works indirectly by virtue of its inhibition of acetylcholinesterase. When the acetyl choline breakdown is completely inhibited and the resulting concentrations of acetylcholine are completely insufficient to remove rocuronium from the receptors, no further effect from a cholinesterase inhibitor can be expected (ceiling effect). [16] Clinical data support this idea as increasing the neostigmine dose from 35 to 50 mcg/kg did not shorten recovery times. [17] Therefore, lack of efficacy of 50 mcg/kg neostigmine in the current study may be a problem of this indirect antagonism rather than an ineffective dose of neostigmine. Although use of inhalation anaesthetics is not anticipated to have an impact on the efficacy of sugammadex [18,19], recovery times with neostigmine may be prolonged. Indeed, sevoflurane anaesthesia must be considered as a reason for the slow and very variable recovery times following neostigmine in the current study. [13] In one study, [20] the median recovery times after neostigmine reversal at reappearance of T2 were prolonged from 8min under propofol to 23 min under sevoflurane and their maxima were prolonged from 11 to 57min. In order to reduce the interference of varying sevoflurane concentrations in the current study, sevoflurane was maintained constant at least until TOF 0.9, but for not longer than 8 min after administration of the reversal drugs. In cases of extremely prolonged recovery, sevoflurane was reduced individually which might have decreased its impact in the most extreme recovery times; as no patient in the sugammadex group had a recovery time outside this 8 min period, sevoflurane wash out would only have an impact on the neostigmine group. Nevertheless, the use of sevoflurane as the maintenance anaesthetic may be considered to decrease the efficacy of neostigmine reversal only. Accordingly, the study design regarding the underlying anaesthesia favours the hypothesis that reversal would be faster with sugammadex than with neostigmine. However, sevoflurane is the most commonly used anaesthetic agent in Europe and it is important to study these reversal agents under clinically relevant conditions. Sugammadex was given as a 2 mg/kg dose in the current study as this appeared to be adequate to restore neuromuscular function in an average time of less than 2 min when administered at reappearance of T2. In the larger population of this comparative study, the median recovery times of less than 2 min met the expectations from the dose-finding studies and confirmed the results of two studies in which sugammadex 2 mg/kg was also given at reappearance of T2 of a rocuronium induced neuromuscular blockade. [18,21] Even more important, the variability of recovery times was clinically irrelevant following reversal with 2 mg/kg sugammadex (95% CI neuromuscular recovery (TOF >0.7 or TOF >0.8) and advocated a time between administration and complete recovery of less than 8 min as acceptable. On the basis of these less advanced end points, in this study, the average recovery times following neostigmine and sugammadex were longer for the TOF 0.9 end point for neostigmine. The clinical and procedural implications of the options supplied by sugammadex have not been investigated, so far. Acceleromyography may at times be associated with less stable twitch responses than other quantitative techniques, such as mechanomyography, even with thoroughly fixed fingers and forearm as carefully done in the current trial. Despite these limitations, acceleromyography is considered an acceptable device for research purposes. [15] It has been suggested that acceleromyography may overestimate recovery of neuromuscular function [22] and that to exclude residual paralysis a TOF ratio of 1.0 should be achieved. [23]

In this study, we considered a TOF ratio of at least 0.9 to be sufficient to allow safe extubation of the patient. However, all patients were carefully monitored in the recovery room and there were no signs of residual paralysis in any patient. As neostigmine is associated with an increased risk for muscarinergic side effects, parasympatholytic anticholinergic drugs such as atropine or glycopyrrolate are added, as was done in this study. Although the use of glycopyrrolate is advantageous, [24] the increase in HR and arterial pressure observed in other studies [25] are confirmed in the current study with this combination due to faster onset of glycopyrrolate compared with neostigmine. [25,26] In the current study, no specific side effects have been observed following sugammadex; however, the study was not powered to decide on the incidence of side effects, and only adds to the database of information available.

Conclusion

Recovery of neuromuscular function after rocuronium to a TOF ratio of 0.9 is faster with 2 mg/kg sugammadex compared with 50 mcg/kg neostigmine. Even more important, 98% of the patients were sufficiently recovered within 2 min following sugammadex but it was 8 min following neostigmine before 98% of patients were sufficiently recovered. The safety profile did not differ between sugammadex-treated and neostigmine-treated patients.

References

1. Kopman AF, Kopman DJ, Ng J, Zank LM. Antagonism of profound cisatracurium and rocuronium block: the role of objective assessment of neuromuscular function. J Clin Anesth. 2005;17(1):30–5.
2. Tramèr MR, Fuchs-Buder T. Omitting antagonism of neuromuscular block: effect on postoperative nausea and vomiting and risk of residual paralysis—a systematic review. Br J Anaesth. 1999;82(3):379–86.
3. Bom A, Bradley M, Cameron K, Clark JK, Van Egmond J, Feilden H, et al. A novel concept of reversing neuromuscular block: chemical encapsulation of rocuronium bromide by a cyclodextrin-based synthetic host. Angew Chem Int Ed Engl. 2002;41(2):266–70.
4. Sorgenfrei IF, Norrild K, Larsen PB, Stensballe J, Ostergaard D, Prins ME, et al. Reversal of rocuronium-induced neuromuscular block by the selective relaxant binding agent sugammadex: a dose-finding and safety study. Anesthesiology. 2006;104(4):667–74.

5. Jones RK, Caldwell JE, Brull SJ, Soto RG. Reversal of profound rocuronium-induced blockade with sugammadex: a randomized comparison with neostigmine. Anesthesiology. 2008;109(5):816–24.
6. Murphy GS. Residual neuromuscular blockade: incidence, assessment, and relevance in the postoperative period. Minerva Anestesiol. 2006;72(3):97–109.
7. Debaene B, Plaud B, Dilly MP, Donati F. Residual paralysis in the PACU after a single intubating dose of an intermediate-acting nondepolarizing muscle relaxant. Anesthesiology. 2003;98(5):1042–8.
8. Shorten GD. Postoperative residual curarisation: incidence, aetiology, and associated morbidity. Anaesth Intensive Care. 1993; 21(6):782–9.
9. Van Vlymen JM, Parlow JL. The effects of reversal of neuromuscular blockade on autonomic control in the perioperative period. Anesth Analg. 1997;84(1):148–54.
10. Fisher DM. Clinical pharmacology of neuromuscular blocking agents. Am J Health Syst Pharm. 1999;56(11 Suppl 1):S4–9.
11. Feinberg M. The problems of anticholinergic adverse effects in older patients. Drugs Aging. 1993;3(4):335–48.
12. Blobner M, Eriksson LI, Scholz J, Motsch J, Della Rocca G, Prins ME. Reversal of rocuronium-induced neuromuscular blockade with sugammadex compared with neostigmine during sevoflurane anaesthesia: a randomized controlled trial. Eur J Anaesthesiol. 2010;27(10):874–81.
13. Reid JE, Breslin DS, Mirakhur RK, Hayes AH. Neostigmine antagonism of rocuronium block during anaesthesia with sevoflurane, isoflurane, or propofol. Can J Anaesth. 2001; 48(4):351–5.
14. Viby-Mogensen J, Engbaek J, Eriksson LI, et al. Good clinical research practice in pharmacodynamic studies of neuromuscular blocking agents. Acta Anaesthesiol Scand. 1996; 40(1):59–74.
15. Fuchs-Buder T, Claudius C, Skovgaard LT, et al. Good clinical research practice in pharmacodynamic studies of neuromuscular blocking agents II: the Stockholm revision. Acta Anaesthesiol Scand. 2007;51(7):789–808.
16. Bartkowski RR. Incomplete reversal of pancuronium blockade by neostigmine, pyridostigmine, and edrophonium. Anesth Analg. 1987;66(6):594–8.
17. McCourt KC, Mirakhur RK, Kerr CM. Dosage of neostigmine for reversal of rocuronium block from two levels of spontaneous recovery. Anaesthesia. 1999;54(7):651–5.
18. Vanacker BF, Vermeyen KM, Struys MM, et al. Reversal of rocuronium induced neuromuscular block with sugammadex is equally effective under propofol or sevoflurane anaesthesia. Anesth Analg. 2007;104(3):563–8.
19. Rex C, Wagner S, Spies C, et al. Reversal of neuromuscular blockade by sugammadex after continuous rocuronium infusion. Anesthesiology. 2009;111(1):30–5.
20. Kim K, Cheong M, Lee H, Lee J. Tactile assessment for reversibility of rocuronium-induced neuromuscular blockade. Anesth Analg. 2004;99(4):1080–5.
21. Flockton EA, Mastronardi P, Hunter JM, et al. Reversal of rocuronium induced neuromuscular block with sugammadex is faster than cisatracurium reversal with neostigmine. Br J Anaesth. 2008;100(5):622–30.
22. Kopman AF, Chin W, Cyriac J. Acceleromyography versus electromyography: comparison of neuromuscular responses. Acta Anaesthesiol Scand. 2005;49(3):316–22.
23. Capron F, Alla F, Hottier C, et al. Can acceleromyography detect low levels of residual paralysis? Anesthesiology. 2004; 100(5): 1119–24.
24. Salem MG, Richardson JC, Meadows GA, et al. Glycopyrrolate versus atropine with neostigmine for reversal of neuromuscular blockade. Br J Anaesth. 1985;57(2):184–7.
25. Mirakhur RK, Jones CJ, Dundee JW. Effects of intravenous glycopyrrolate and atropine in anaesthetised patients. Anaesthesia. 1981;36(3):277–81.
26. Heier T, Clough D, Wright PM, et al. Influence of mild hypothermia on pharmacokinetics and action of neostigmine. Anesthesiology. 2002;97(1):90–5.