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COMPARISON OF SAFETY AND EFFECTIVENESS OF SUGAMMADEX AND NEOSTIGMINE ON NEUROMUSCULAR BLOCKADE USING TIME FROM END OF SURGERY TO EXTUBATION USING NEUROMUSCULAR MONITORING, HEMODYNAMIC PARAMETERS AND STUDY THEIR POST OP COMPLICATION

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Abstract

Background: Timely and reliable reversal of non-depolarizing neuromuscular blockade is critical in elective surgeries to enable safe extubation and efficient operating room (OR) turnover. This study compared the safety and effectiveness of sugammadex versus neostigmine–glycopyrrolate for reversal of vecuronium-induced blockade, focusing on time to extubation under train-of-four (TOF) monitoring, recovery intervals, and postoperative complications. ***Methods:*** In this analytical cross-sectional study, 200 adults (ASA I–II; 20–60 years) undergoing elective surgery under general anaesthesia were allocated by alternate assignment to receive either sugammadex 2 mg/kg (Group A, n=100) or neostigmine 0.05 mg/kg with glycopyrrolate 0.01 mg/kg (Group B, n=100) at reappearance of the second twitch (T2). The primary outcome was time from end of surgery to extubation (TOF ratio ≥0.9). Secondary outcomes included time from the last vecuronium dose to TOF 0.9, time from study drug to OR discharge readiness, and postoperative adverse events. ***Results:*** Baseline demographics were comparable between groups (all p>0.05). The time from the last vecuronium dose to TOF 0.9 was shorter with sugammadex (18.62±2.01 min) than neostigmine (27.15±3.22 min; p=0.001). From study drug administration to extubation, Group A recovered faster (2.82±0.51 min) than Group B (13.99±2.10 min; t=−23.82, p=0.001). Operating room discharge readiness was earlier with sugammadex (8.71±4.10 min) compared with neostigmine (24.11±9.86 min; p=0.001). Postoperative events were infrequent, with PONV occurring in 2% of Group A and 5% of Group B and POUR in 1% and 3% of Groups A and B, respectively. No postoperative residual paralysis or serious drug-related events occurred, and between-group differences in adverse events were not significant (p=0.802). ***Conclusions:*** Sugammadex provided a faster and more predictable reversal of vecuronium-induced neuromuscular blockade than neostigmine–glycopyrrolate, enabling earlier extubation and OR discharge readiness with a similarly low complication rate. These findings support sugammadex use when rapid recovery and operating room efficiency are priorities.

Keywords: Sugammadex, Neostigmine, neuromuscular blockade, train-of-four monitoring, extubation time.

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INTRODUCTION

General anesthesia is a controlled pharmacological state that provides unconsciousness, amnesia, analgesia, muscle relaxation, and attenuation of autonomic responses to surgical stimuli. [1] Among these, skeletal muscle relaxation is vital for achieving smooth tracheal intubation, immobility, and optimal surgical field exposure. Neuromuscular blockade management is central to modern anesthesia practice, ensuring ideal surgical conditions and patient safety. Train-of-four (TOF) monitoring remains the standard for assessing the depth of neuromuscular blockade and guiding reversal, thereby reducing the risk of residual paralysis and postoperative respiratory complications.

Vecuronium bromide, an intermediate-acting non-depolarizing neuromuscular blocking agent (NMBA), is widely used due to its predictable action, minimal cardiovascular effects, and absence of histamine release. [2-4] Its metabolism depends primarily on hepatic function and partly on renal excretion. Despite its safety,

incomplete or delayed reversal can result in postoperative hypoventilation, airway obstruction, or delayed awakening, emphasizing the importance of careful neuromuscular monitoring and timely reversal. [5,6]

Neostigmine, an acetylcholinesterase inhibitor, has long been used to reverse non-depolarizing blockade by increasing acetylcholine concentration at the neuromuscular junction. However, its efficacy varies with blockade depth, and the excess acetylcholine also stimulates muscarinic receptors, causing bradycardia, arrhythmias, and bronchoconstriction. Anticholinergics like atropine or glycopyrrolate are used to counteract these effects but may induce tachycardia. [7-9]

Sugammadex, a selective relaxant binding agent (SRBA) and modified gamma-cyclodextrin, represents a major advancement in reversal pharmacology. It directly encapsulates steroidal NMBAs such as vecuronium and rocuronium, producing rapid, predictable, and complete reversal without muscarinic stimulation or anticholinergic use. Studies have shown that sugammadex offers faster recovery, greater hemodynamic stability, and fewer postoperative respiratory complications than neostigmine. [10-15]

Despite this, comparative research evaluating recovery effects under routine surgical conditions is valuable. [16] The present study aims to compare the safety and effectiveness of sugammadex and neostigmine in reversing vecuronium-induced neuromuscular blockade, focusing on time from end of surgery to extubation using TOF monitoring, hemodynamic parameters, and postoperative complications.

MATERIALS AND METHODS

After approval from the Institutional Ethics Committee and obtaining written informed consent, this analytical cross-sectional study was conducted in the Department of Anaesthesiology at Sri Aurobindo Medical College and Postgraduate Institute, Indore (M.P.). A total of 200 adult patients were enrolled during the study period. Patients were of either sex, aged between 20 and 60 years, belonging to American Society of Anesthesiologists (ASA) physical status I and II, and scheduled for elective surgical procedures under general anaesthesia.

Inclusion Criteria:

- Patients aged between 20 and 60 years.
- Patients of either sex.
- ASA physical status I and II.
- Mallampati grade I and II.
- Patients posted for elective surgeries under general anaesthesia.

Exclusion Criteria:

- Patients with severe renal impairment.
- Patients receiving antiemetic or interacting medications.
- Patients administered additional antimuscarinic agents such as atropine intraoperatively.
- Patients unwilling to participate.

Sample Size Calculation:

Sample size was calculated using the standard formula for estimation of proportion:

$n=(Z^2\times p\times q)/d^2$

Where:

- n = required sample size
- Z = standard normal deviate at 95% confidence level (1.96)
- p = expected proportion
- q = 1 − p
- d = allowable error

Considering feasibility and institutional surgical load, a total of 200 patients were included in the study and equally allocated into two groups, with 100 patients in each group.

Methodology

All patients underwent pre-anaesthetic evaluation and routine investigations. An informed written consent was taken from all the patients. They were kept nil per oral for six hours and preloaded with 500 mL of lactated Ringer's solution. Baseline heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and oxygen saturation (SpO_2) were recorded before induction.

Patients were divided into two groups by the alternate (odd-even) method.

- Group A: Patients received Sugammadex 2 mg/kg intravenously for reversal of neuromuscular blockade. [N=100]
- Group B: Patients received Neostigmine 0.05 mg/kg with Glycopyrrolate 0.01 mg/kg intravenously for reversal. [N=100]

Anaesthetic Technique: Anaesthesia was induced with standard agents, and muscle relaxation was achieved using Vecuronium 0.12 mg/kg in Group A and Group B. At the end of surgery, patients received the assigned reversal drug regimen as per their group.

Neuromuscular Monitoring: Neuromuscular function was assessed using a peripheral nerve stimulator applied over the ulnar nerve at the wrist to elicit adductor pollicis contractions. The train-of-four (TOF) method was used, consisting of four electrical stimuli at 0.5-second intervals. The number of twitches and the TOF ratio (T4/T1) were recorded to evaluate the degree of

neuromuscular recovery. A TOF ratio ≥0.9 was considered adequate for extubation.

Outcome Measures: The primary outcome was the time from the end of surgery to extubation, as measured by TOF monitoring. Secondary outcomes included intraoperative and postoperative hemodynamic parameters (HR, SBP, DBP, MAP, SpO_2) and postoperative complications such as residual blockade or arrhythmias.

Statistical Analysis

Data were recorded prospectively in a pre-structured proforma and compiled in a master chart using Microsoft Excel 2020. Quantitative data were presented as mean ± standard deviation, and categorical data as frequencies and percentages. Group comparisons were made using the independent t-test or Mann-Whitney U test, as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 200 patients were enrolled in the study and divided equally into two groups of 100 each. The demographic parameters such as age, sex, body weight, ASA grade, Mallampati grade, and mean duration of surgery were comparable between both groups, showing no statistically significant difference ($p > 0.05$), confirming homogeneity of the study population. [Table 1]

Table 1. Comparison of Demographic and Baseline Parameters

Parameter	Group A (n = 100)	Group B (n = 100)	*p*-value
Age (years, Mean ± SD)	42.26 ± 10.34	43.02 ± 9.88	0.482
Weight (kg, Mean ± SD)	63.15 ± 6.42	62.82 ± 6.56	0.624
Sex (M/F)	58/42	61/39	0.663
ASA Grade I/II	56/44	59/41	0.612
Mean Duration of Surgery (min)	78.34 ± 12.60	80.26 ± 13.22	0.218

NS = non-significant (p > 0.05)

The mean time from the last maintenance dose of vecuronium to recovery of TOF ratio of 0.9 was 18.62 ± 2.01 minutes in Group A (Sugammadex) and 27.15 ± 3.22 minutes in Group B (Neostigmine), which was statistically highly significant ($p = 0.001$). The mean time from study drug administration (at reappearance of the second twitch, T2) to tracheal extubation, corresponding to a TOF ratio ≥ 0.9, was significantly shorter with Sugammadex compared to Neostigmine. The mean time was 2.82 ± 0.51 minutes in Group A and 13.99 ± 2.10 minutes in Group B, showing a highly significant difference ($t = -23.82$, $p = 0.001$). This indicates that Sugammadex achieved markedly faster reversal and earlier readiness for extubation compared to Neostigmine. Similarly, the mean time from study drug administration to operating room discharge readiness was 8.71 ± 4.10 minutes in Group A and 24.11 ± 9.86 minutes in Group B, which was also highly significant ($p = 0.001$). Patients receiving Sugammadex exhibited smoother recovery profiles and earlier transfer readiness from the operating theatre to the post-anaesthesia care unit. [Table 2]

Table 2. Time Intervals Related to Recovery and Operating Room Readiness

Parameter	Group A (Mean ± SD)	Group B (Mean ± SD)	*p*-value
Time from last vecuronium dose to TOF 0.9 (min)	18.62 ± 2.01	27.15 ± 3.22	0.001
Time from study drug to extubation (min)	2.82 ± 0.51	13.99 ± 2.10	0.001
Time from study drug to OR discharge readiness (min)	8.71 ± 4.10	24.11 ± 9.86	0.001

HS = Highly Significant (p < 0.001)

Regarding postoperative adverse effects, 2 patients (2%) in Group A experienced postoperative nausea and vomiting (PONV), and 1 patient (1%) had postoperative urinary retention (POUR). In Group B, 5 patients (5%) developed PONV and 3 patients (3%) had POUR. No cases of postoperative residual paralysis (PORP) were observed in either group. The difference in postoperative side effects between the two groups was statistically non-significant ($p = 0.802$). No serious drug-related adverse events or allergic reactions were reported in any patient during the perioperative or recovery period. Overall, Sugammadex demonstrated significantly faster and more predictable reversal of neuromuscular blockade, with better hemodynamic stability and fewer postoperative complications, compared to Neostigmine–Glycopyrrolate combination. [Table 3]

Table 3. Post-operative Adverse Effects

Post-operative Complication	Group A (n = 100)	Group B (n = 100)	*p*-value
Post-operative nausea/vomiting (PONV)	2 (2%)	5 (5%)	0.802
Post-operative residual paralysis (PORP)	0 (0%)	0 (0%)	–
Post-operative urinary retention (POUR)	1 (1%)	3 (3%)	0.842

NS = Not Significant (p > 0.05)

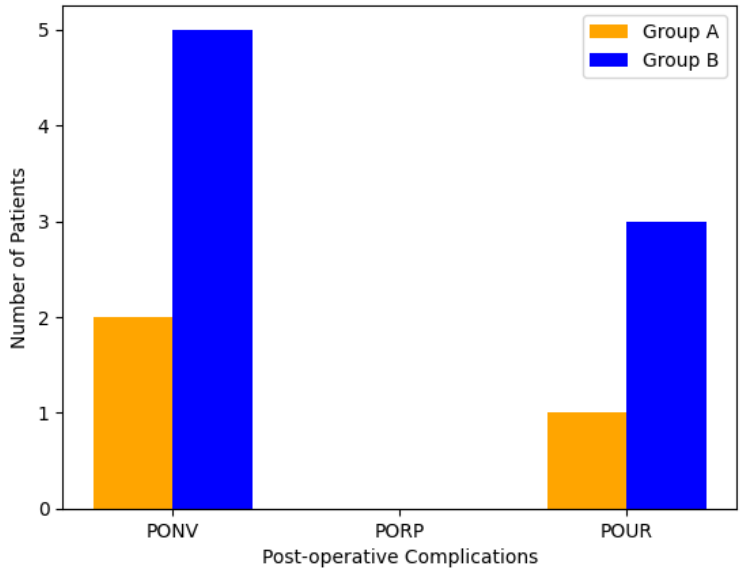

Figure 3: Comparison of post-operative side effects (PONV, PORP, POUR).

DISCUSSION

The present analytical cross-sectional study was conducted to compare the safety and efficacy of Sugammadex and Neostigmine in reversing vecuronium-induced neuromuscular blockade in adult patients undergoing elective surgeries under general anaesthesia. The comparison was made based on neuromuscular monitoring (TOF ratio), time to extubation, hemodynamic parameters, and postoperative complications.

In our study, both groups were comparable in terms of demographic and baseline characteristics, including age, sex, weight, ASA grade, Mallampati score, and mean duration of surgery (p>0.05). This ensured that any difference in outcomes could be attributed to the reversal agents rather than demographic variability. This was comparable to studies done by Sharma et al. [1] and Tsai YH et al. [11].

In our study, the mean time from study drug administration at reappearance of the second twitch (T2) to tracheal extubation was significantly shorter in the Sugammadex group (2.82±0.51 min) compared to the Neostigmine group (13.99±2.10 min; p=0.001). Additionally, the mean time from the last maintenance dose of vecuronium to recovery of a TOF ratio ≥0.9 was 18.62±2.01 minutes in the Sugammadex group (Group S) and 27.15±3.22 minutes in the Neostigmine group (Group N), which was highly significant (p=0.001). These findings indicate that Sugammadex achieved a faster and more predictable recovery from neuromuscular blockade, consistent with its direct encapsulation mechanism that inactivates vecuronium molecules, rendering them unavailable at the neuromuscular junction.

Our results are in agreement with the meta-analysis conducted by Hristovska et al. (2018), which included 10 randomized controlled trials and reported mean reversal times of 2.0 minutes for Sugammadex and 12.9 minutes for Neostigmine. [10] Likewise, Khuenl-Brady et al. (2010) demonstrated a mean reversal time of 2.7 minutes with Sugammadex compared to 17.9 minutes with Neostigmine, confirming the superior efficacy of Sugammadex in achieving rapid and complete reversal of neuromuscular block. [17] Similarly, Sharma et al. (2024) reported that the mean time from study drug administration (at the reappearance of the second twitch, T2) to tracheal extubation was 2.84+_0.59 minutes with Sugammadex and 14.17+_2.35 minutes with Neostigmine, a statistically highly significant difference (p=0.001), further emphasizing the faster and more predictable recovery provided by Sugammadex. [1]

In the present study, the mean time from study drug administration to operating room discharge readiness was 8.71±4.10 minutes in Group A and 24.11±9.86 minutes in Group B, a highly significant difference (p=0.001). Our findings align with Putz et al. (2016), who reported OR discharge times of 9.15±4.28 minutes

with sugammadex and 13.87±11.43 minutes with neostigmine (p=0.005) [18], and with Brueckmann et al. (2015), who observed discharge readiness at 14.7 minutes for sugammadex versus 18.6 minutes for neostigmine [19]. Consistent with Sharma et al. (2024), the mean time from study drug administration at the reappearance of T2 to extubation was 2.84±0.59 minutes in Group A and 14.17±2.35 minutes in Group B, a highly significant difference (p=0.001) [1]. Taken together, these results underscore the more rapid and predictable recovery achieved with sugammadex.

In our study, postoperative complications such as nausea, vomiting, urinary retention, and residual paralysis were also evaluated. Postoperative nausea and vomiting (PONV) occurred in 2% of patients in Group A and 5% in Group B, while postoperative urinary retention (POUR) was seen in 1% of Group A and 3% of Group B. No patient in either group experienced postoperative residual paralysis (PORP). Although the difference in postoperative complications was statistically insignificant (p=0.802), the incidence was slightly lower in the Sugammadex group, suggesting a better safety profile. These findings are in agreement with those of Khuenl-Brady et al. (2010), who observed that adverse effects such as dry mouth, altered heart rate, or PONV were less frequent with Sugammadex (14.6%) compared to Neostigmine (22.2%). [17] The absence of muscarinic stimulation with Sugammadex accounts for its improved tolerability and hemodynamic stability. Comparable trends were noted by Sharma et al. (2024), who also reported no major adverse drug reactions or allergic events in either group. [1] PONV occurred in 2% of patients in the sugammadex group and 5% in the neostigmine group, while POUR was seen in 1% and 3%, respectively; PORP was not observed in any patient. Although the between-group differences were not statistically significant (p>0.05), the lower rate of minor complications with sugammadex supports a more favorable safety profile.

Overall, the present study demonstrates that Sugammadex provides a faster, smoother, and more reliable recovery from vecuronium-induced neuromuscular blockade than Neostigmine. Its use minimizes the risk of residual paralysis, facilitates early extubation, and shortens OR discharge time—all crucial in improving perioperative efficiency and patient outcomes. The main limitation of the present study was the moderate sample size (n=200), conducted at a single center. Although the results were statistically significant, multicentric studies with larger populations are needed to confirm the findings. Additionally, cost constraints remain a major limitation to the widespread use of Sugammadex in developing countries like India, where Neostigmine continues to be the preferred reversal agent due to its affordability.

CONCLUSION

In adults undergoing elective surgery under general anaesthesia, sugammadex was superior to neostigmine–glycopyrrolate for reversal of vecuronium-induced neuromuscular blockade. Sugammadex shortened the time to TOF ratio ≥ 0.9, enabled markedly earlier extubation, and reduced time to operating room discharge readiness. These advantages were observed in the setting of comparable baseline characteristics between groups. Postoperative adverse events were low and similar across groups, with a numerically lower incidence of minor complications such as PONV and urinary retention in the sugammadex cohort. No cases of postoperative residual paralysis and no serious drug-related events occurred in either arm.

The findings support the use of sugammadex when rapid, reliable recovery and efficient operating room turnover are priorities, particularly where minimizing hemodynamic fluctuation and residual blockade is important. Cost remains a practical barrier to universal adoption in resource-limited settings. Future multicentre trials with larger, diverse populations and formal cost-effectiveness analyses are warranted to refine patient selection and inform policy. Overall, sugammadex offers a faster and more predictable reversal profile than neostigmine with at least comparable safety, and may improve perioperative workflow and patient outcomes.

REFERENCES

1. Sharma A, Chatrath V, Marwah D, Kamboj A, Gupta M, Arora A. Comparative evaluation of sugammadex versus neostigmine for reversal of neuromuscular blockade in patients undergoing cholecystectomy under general anaesthesia. Int J Sci Stud. 2024;12(8):27–31.
2. Bowman WC. Neuromuscular block. Br J Pharmacol. 2006;147(Suppl 1):S277–86.
3. Tarbeeh GA, Othman MM. The pharmacodynamics of vecuronium in chronic renal failure patients: the impact of different priming doses. Ren Fail. 2012;34(7):827–33.
4. Craig RG, Hunter JM. Neuromuscular blocking drugs and their antagonists in patients with organ disease. Anaesthesia. 2009;64(1):55–65.
5. Baillard C, Gehan G, Reboul-Marty J, Larmignat P, Samama CM, Cupa M. Residual curarization in the recovery room after vecuronium. Br J Anaesth. 2000;84:394–5.
6. Fuchs-Buder T, Mencke T. Use of reversal agents in day care procedures (with special reference to postoperative nausea and vomiting). Eur J Anaesthesiol Suppl. 2001;18:53–9.
7. Fielder DL, Nelson DC, Andersen TW, Gravenstein JS. Cardiovascular effects of atropine and neostigmine in man. Anesthesiology. 1969;30:637–41.

8. Mirakhur RK, Dundee JW, Jones CJ, Coppel DL, Clarke RS. Reversal of neuromuscular blockade: dose determination studies with atropine and glycopyrrolate given before or in a mixture with neostigmine. Anesth Analg. 1981;60:557–62.
9. Welliver M, McDonough J, Kalynych N, Redfern R. Discovery, development, and clinical application of sugammadex sodium, a selective relaxant binding agent. Drug Des Devel Ther. 2009;2:49–59.
10. Hristovska AM, Duch P, Allingstrup M, Afshari A. The comparative efficacy and safety of sugammadex and neostigmine in reversing neuromuscular blockade in adults: a Cochrane systematic review with meta-analysis and trial sequential analysis. Anaesthesia. 2018;73:631–41.
11. Tsai YH, Chen CY, Wong HF, Chou AH. Comparison of neostigmine and sugammadex for hemodynamic parameters in neurointerventional anesthesia. Front Neurol. 2023;14:1045847.
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: results of a randomised controlled trial. Eur J Anaesthesiol. 2010;27:874–81.
13. Lemmens HJ, El-Orbany MI, Berry J, Morte JB, Martin G. Reversal of profound vecuronium-induced neuromuscular block under sevoflurane anesthesia: sugammadex vs. neostigmine. BMC Anesthesiol. 2010;10:15.
14. Keating GM. Sugammadex: a review of neuromuscular blockade reversal. Drugs. 2016;76:1041–52.
15. Brull SJ, Naguib M. Elective reversal of muscle relaxation in general anaesthesia: focus on sugammadex. Drug Des Devel Ther. 2009;3:119–29.
16. Farag E, Rivas E, Bravo M, Hussain S, Argalious M, Khanna S, et al. Sugammadex vs neostigmine for reversal of rocuronium neuromuscular block in patients having catheter-based neurointerventional procedures: a randomized trial. Anesth Analg. 2021;132:1666–76.
17. Khuenl-Brady KS, Wattwil M, Vanacker BF, Lora-Tamayo JI, Rietbergen H, Álvarez-Gómez JA. Sugammadex provides faster reversal of vecuroniuminduced neuromuscular blockade compared with neostigmine: A multicenter, randomized, controlled trial. Anesth Analg 2010;110:64-73.
18. Putz L, Dransart C, Jamart J, Marotta ML, Delnooz G, Dubois PE. Operating room discharge after deep neuromuscular block reversed with sugammadex compared with shallow block reversed with neostigmine: A randomized controlled trial. J Clin Anesth 2016;35:107-13.
19. Brueckmann B, Sasaki N, Grobara P, Li MK, Woo T, de Bie J, et al. Effects of sugammadex on incidence of postoperative residual neuromuscular blockade: A randomized, controlled study. Br J Anaesth 2015;115: 743-51.