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Original Research Article

Comparative Evaluation of Sugammadex Versus Neostigmine for Reversal of Neuromuscular Blockade in Patients Undergoing Surgery Under General Anesthesia

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Conflict of interest: Nil

Abstract

Introduction: Neuromuscular blocking agents are commonly used during general anesthesia to facilitate endotracheal intubation and optimize surgical operations. Timely and effective reversal is crucial to prevent residual paralysis and postoperative complications.

Aims: To evaluate and compare the efficacy and safety of sugammadex and neostigmine in reversing neuromuscular blockade in patients undergoing surgery.

Settings and Design: A prospective parallel arm quasi-experimental study conducted at a tertiary care hospital, involving 40 adult patients undergoing elective surgery under general anaesthesia.

Methods and Material: Patients were alternatively allocated into group S (n=20), received Sugammadex 2mg/kg and group N (n=20) received Neostigmine 0.05mg/kg with Glycopyrrolate 0.01mg/kg at the return of the second twitch on Train of Four (TOF) monitoring.

Results: Baseline characteristics were comparable between groups. Sugammadex significantly reduced recovery time to TOF ≥ 0.9 (4.12±1.91 min) compared to neostigmine (12.25 ± 2.94 min; $p<0.001$). The time M1 and M2 was also shorter in the sugammadex group ($p < 0.01$). Postoperative heart rate and blood pressure were significantly lower in the sugammadex group ($p<0.05$).

Conclusions: Sugammadex provides a faster, safer, and more hemodynamically stable reversal of neuromuscular blockade than neostigmine in adult surgical patients.

Keywords: Neuromuscular blockade, TOF monitoring, Hemodynamic stability.

Key Messages: Neuromuscular Blocking Agents leads to significant complications and delayed recovery. The adoption of Sugammadex has been linked to operational benefits, compared to Neostigmine, thereby we seek to evaluate the comparative advantages and limitation of both agents in optimizing patient outcome and perioperative care.

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Introduction

Neuromuscular blocking agents (NMBAs) are widely used in general anaesthesia to facilitate intubation, improve surgical conditions, and ensure patient immobility [1,2].

However, residual neuromuscular blockade remains a significant concern, affecting 20–40% of patients and increasing the risk of postoperative respiratory complications such as hypoxemia and pneumonia[3,4]. Neostigmine, a conventional reversal agent, may cause adverse cardiovascular effects[1].

Sugammadex, a novel agent approved for reversing rocuronium and vecuronium-induced blockade, provides faster and more specific reversal with fewer systemic effects[5,6]. Objective neuromuscular monitoring using train-of-four (TOF) is essential to ensure safe and complete recovery.

Materials and Methods

Ethics: This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and Good Clinical Practice (GCP) guidelines. Approval was obtained from the Institutional Ethics Committee (IEC Ref No.: Blinded for peer review). The study was also registered with the Clinical Trials Registry of India (CTRI Reg No.: CTRI/2026/03/106549). Written informed consent was obtained from all participants prior to enrolment. Confidentiality and anonymity of patient data were strictly maintained throughout the study.

Study Design: This is a prospective parallel arm quasi-experimental study conducted in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines at a tertiary care hospital and informed written consent.

Study Population: It was derived from patients presenting for elective surgery at the institution during the study period. A total of 40 patients were selected from them excluding the ones not meeting the criteria and then assigning them number alternately. Odd number group were taken under Group S(n=20) given sugammadex as reversal and even number taken under group N(n=20) given neostigmine as reversal.

Inclusion Criteria

1. Age: 18 -60 years
2. ASA grade I, II, III
3. Duration of surgery >=2 hours
4. Body mass index (18-25 kg/m^2)
5. Informed consent

Exclusion Criteria

1. Patients with significant pre-existent pulmonary, renal or neuromuscular disorders
2. Pregnant women
3. Previous history of post-operative nausea and vomiting, motion sickness
4. Previous history of hypersensitivity to study medications

Study Parameters

1. M1: Mean time from last maintenance dose of vecuronium to recovery of TOF ratio>= 0.9
2. M2: Mean time from study drug administration at reappearance of second twitch T2 after last dose of vecuronium to tracheal extubation
3. M3: Mean time from study drug administration to operating room discharge ready

Study Method: A detailed pre-anesthetic check-up including general, clinical and airway assessment was done before surgery. Patients instructed to fast for 8 hours for solids and 2 hours for clear fluids. On the day of surgery, standard monitoring including non-invasive blood pressure, pulse oximetry, electrocardiogram, and end tidal carbon dioxide (Datex – Ohmeda, GE Healthcare, USA), and neuromuscular monitoring were attached as per standardized anesthesia protocol on arrival to operation theatre before induction of anesthesia. The anesthesiologist was un-blinded to the study drug, as he/she needed to be able to adjust the anaesthesia and neuromuscular blockade according to the treatment group, and assess the effects of sugammadex on the patient flow through the operatingroom. Anesthesia induction achieved using intravenous propofol (2 mg/kg; Akshar Pharma, India), fentanyl (2 µg/kg; Sun Pharma, India), and depolarizing neuromuscular blockade succinylcholine (2 mg/kg; Neon Laboratories, India) and maintenance with isoflurane (Drägerwerk AG & Co., Germany) at 1 MAC with 50% oxygen-nitrous oxide mixture. Post-intubation neuromuscular blockade induced using vecuronium (0.12 mg/kg loading dose, followed by 0.03 mg/kg maintenance; Cipla Ltd., India). On completion of surgery, all anesthetic gases were stopped and inspiratory oxygen concentration increased to 100% 5 minutes before extubation and suctioning done. After surgery, using neuromuscular monitoring, when train of four shows two twitches, group S is administered sugammadex (2 mg/kg; Neon Pharmaceuticals, India) intravenous and group N is administered neostigmine (0.05 mg/kg) with glycopyrrolate (0.01 mg/kg; Neon Pharmaceuticals, India) for reversal. The neuromuscular monitoring recorded and time required to achieve TOF recovery and time required to achieve 90%of TOF measured.

Extubation was done on return of spontaneous ventilation when TOF ratio reached ≥0.9. In recovery room, patient received oxygen through simple oxygen mask and monitoring was done.

Statistics Analysis: Sample size was calculated using G*Power software (version 3.1.9.2), using the formula for comparison of two independent means. Assuming a minimum detectable difference of 5 minutes with a standard deviation of 5 minutes, α = 0.05, and power = 85%, the required sample size was approximately 19 patients per group, rounded to 20 per group. Data were analysed using Student's t-test for continuous variables and Chi-square test for categorical variables. A p-value <0.05 was considered statistically significant.

Results

Table 1: Comparison of baseline characteristics in both group (N=40)

Variable	Sugammadex (n=20)	Neostigmine (n=20)	*p*-value
Age (years)	38.00 ± 12.40	38.70 ± 13.24	0.864
Weight (kg)	62.30 ± 8.02	64.95 ± 6.40	0.255
Height(m)	1.662 ± 0.071	1.677 ± 0.056	0.480
BMI (kg/m²)	22.33 ± 2.19	22.88 ± 1.58	0.369
Sex	13 M / 7 F	13 M / 7 F	1.000
ASA Status	I: 6 II: 11 III: 3	I: 8 II: 8 III: 4	0.637

Table 2: Intraoperative and Recovery Characteristics

Variable	Sugammadex (n=20)	Neostigmine (n=20)	*p*-value
M1(min)	32.95 ± 7.84	40.00 ± 7.63	0.006
M2(min)	2.44 ± 1.17	10.40 ± 2.82	<0.001
M3 (TOF ≥ 0.9)	4.12 ± 1.91	12.25 ± 2.94	<0.001

Table 3: Preoperative and Postoperative Clinical Parameters.

Parameter	Sugammadex (n=20)	Neostigmine (n=20)	*p*-value
Pre-operative SBP mm Hg	126.50 ± 15.77	127.00 ± 12.04	0.911
Post-operative SBP mm Hg	133.40 ± 10.18	144.90 ± 10.89	0.001
Pre-operative DBP mm Hg	77.70 ± 8.64	77.90 ± 7.06	0.93
Post-operative DBP mm Hg	77.00 ± 6.79	89.50 ± 8.33	<0.001
Pre-operative HR (bpm)	81.55 ± 13.84	77.35 ± 7.52	0.24
Post-operativeHR (bpm)	85.00 ± 9.30	107.85 ± 9.38	<0.001

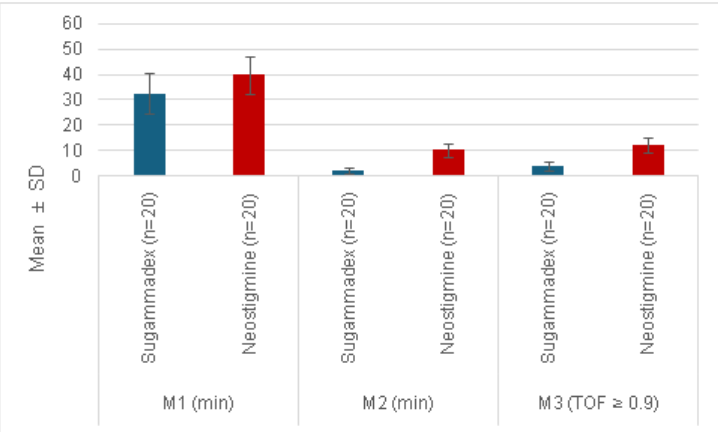

Figure 1: Bar Graph Comparing the Intraoperative and Recovery Characteristics in both groups

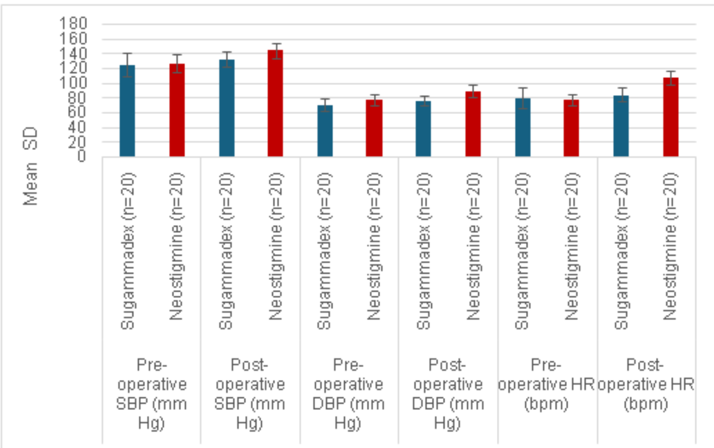

Figure 2: Bar graph representing comparison of SBP and HR in both groups during Preoperative and Postoperative Clinical Parameters.

There were no statistically significant differences in age, weight, height, or BMI. The distribution of sex and ASA physical status was also similar, indicating baseline homogeneity.

Sugammadex group demonstrated significantly faster recovery in all time-based parameters. The time from administration of last dose of vecuronium to recovery TOF≥0.9 (M1) was shorter in the Sugammadex group compared to the Neostigmine group. Likewise, the time to near-complete recovery to extubation (M2) was substantially shorter in the Sugammadex group compared to the Neostigmine group. Most notably, the time to achieve a Train-of-Four (TOF) ratio ≥ 0.9 and discharge from operating room (M3) was significantly reduced in the Sugammadex group compared to the Neostigmine group, reflecting more rapid and predictable neuromuscular recovery.

Preoperative vital signs, including systolic and diastolic blood pressures and heart rate, showed no statistically significant differences between groups, indicating baseline hemodynamic stability. However, postoperative measurements revealed notable differences. Postoperative systolic blood pressure was significantly lower in the Sugammadex group compared to the Neostigmine group. Similarly, postoperative diastolic blood pressure was significantly lower in the Sugammadex group than in the Neostigmine group. The postoperative heart rate was also significantly lower in the Sugammadex group compared to the Neostigmine group, suggesting better postoperative hemodynamic control with Sugammadex.

Postoperative complications were infrequent in both groups. Postoperative nausea and vomiting (PONV) occurred in only one patient in the Sugammadex group and was not observed in the Neostigmine group, with no statistically significant difference. Respiratory problems (PORP) were noted exclusively in the Neostigmine group, while none occurred in the Sugammadex group. No cases of postoperative urinary retention (POUR) were reported in either group. Overall, while adverse events were minimal, the Sugammadex group exhibited a more favourable profile.

Discussion

Since sugammadex first became commercially available in 2008, voluminous literature has emerged detailing the drug's pharmacology, safety and clinical uses. In 2016,articles by de Boer et aldescribed a new and promising agent.7 Sugammadex forms 1:1 complexes with amino steroid neuromuscular blocking drug molecules but has no effect on benzylisoquinolinium compounds or on succinylcholine.[8] Our research demonstrates the efficacy of sugammadex in faster reversal of patients based on all time-based parameters. The patients' demographic profiles in both Group Sugammadex and Group Neostigmine shows similar division of male and female (65% male and 35% female) and age, BMI and ASA grading are all not significant(p<1.000).

Sugammadex shows faster recovery TOF≥0.9 (M1) (32.95±7.84 min) compared to neostigmine group (40.00 ±7.63 min) (p=0.006) and shorter time of discharge from operating room (M3) for sugammadex (4.12 ± 1.91 min) and neostigmine (12.25 ± 2.94 min). This results aligns with previous studies ,including Hristovska A et al meta-analysis, which documented sugammadex 2mg/kg reversed moderate neuromuscular blockade from second twitch of TOF >0.9 in 2.0 min in comparison with 12.9 min for neostigmine 0.05 mg/kg.[9] Similarly, Fiorda Diaz J et al , observed reduction in recovery time to TOF ratio≥0.9 by nearly 67% with sugammadex compared to neostigmine, emphasizing its clinical efficacy in both moderate and deep neuromuscular blockade.[10] Another study Lemmens et al 2010,the geometric mean time to TOF ratio of 0.9 was 3.6 minutes in sugammadex group versus 91 minutes in neostigmine group in analysis including only those patients with recorded time to TOF 0.9 (n=41 in sugammadex group and n=15 in neostigmine group).[11] Another study Grintescu et al. compared recovery time in 34 patients undergoing laparoscopic cholecystectomy who received either sugammadex 2mg/kg or neostigmine 50µg/kg for moderate neuromuscular blockade reversal. Faster recovery time from time between administration of drug and time of extubation with use of sugammadex (1.2±0.8) versus neostigmine (16.7±6.9 min) (p<0.001).[12]

Above results are more significant in certain types of surgery such as laparoscopic surgery where deep level of neuromuscular blockade may permit improved surgical access and enhanced visual field. Neostigmine is generally considered only effective for reversal of neuromuscular blockade if there has been some degree of spontaneous recovery. Use of sugammadex may allow anesthetists to maintain deep level of neuromuscular blockade towards end of surgery, without risking incomplete recovery or other complications.

In our study, post operative nausea and vomiting was observed in 5% (one patient) in sugammadex group and not observed in neostigmine group, however respiratory problems (PORP) noted exclusively in Neostigmine group (2 patients,10%), while none occurred in sugammadex group (p=0.487) suggests that a minor trade-off between minor gastrointestinal effects and more clinically significant respiratory outcomes. No cases of postoperative urinary retention (POUR)were seen in either group. Overall, sugammadex group exhibited comparatively better safety profile. Previous study by Geldner et al 2012, showed adverse events in 11% patients of sugammadex and 24% patients in neostigmine group.[13] Another study, Fiorda Diaz et al 2022, shows overall incidence of post-operative complications was 21.6%. Urinary retention and shortness of breath were reported in group N (only 5.4% and 2.7% of patients respectively), whereas higher incidence of post-operative nausea and vomiting was observed in group S (22.22% versus 5.26%). Another study by G.V.Cammu,V.Smet et al studied comparison of postoperative respiratory curarisation with neostigmine and sugammadex. Their study showed 15% of neostigmine reversed patients had PORC in PACU compared to 2% of patients sugammadex reversed.[14]

We found that sugammadex caused more stable hemodynamic changes and related parameters increase were more notable in patients administered neostigmine. Post -operative blood pressure was significantly lower in sugammadex group (77.00±6.79 mmHg) than in Neostigmine group (89.50±8.33 mmHg) ;(p<0.001). The post-operative heart rate was also significantly lower in sugammadex group (85.00±9.30 bpm) compared to neostigmine (107.85±9.38 bpm; p<0.001).

A previous study by Tsai et al. studies total of 61 patients. Period A defined as average from reversal both 2 min and 5 min and period B data was defined as average from 10 min and 15 min after reversal. The results demonstrated that the increase in MAP from period A to B was significantly greater in Group N than in Group S,MAP level was significantly 95.1 vs 102.4 mmHg, p=0.015) but not altered in group S.[15] Kheunl-Brady et al. also showed that higher heart rate and blood pressure were noted in patients using neostigmine in a study of ASA I to III patients older than 18 years of age. Although, sugammadex has more apparent benefits than neostigmine, it has limitations.[16] Some studies indicated that cost and resources of sugammadex are uncertain as neostigmine has continued to be the drug most often utilized Kim et al even mentioned in their studies that cost of sugammadex impacted their patient selection.[17]

Conclusion

The present study demonstrates that both groups were comparable in baseline demographic and clinical characteristics, confirming baseline comparability following systemic assignment. Sugammadex provided significantly faster and more predictable neuromuscular recovery compared to neostigmine, as evidenced by reduced time to all recovery milestones and earlier attainment of adequate TOF ratio. Hemodynamic parameters remained stable preoperatively in both groups; however, postoperative values showed better cardiovascular stability in the sugammadex group. Although postoperative complications were infrequent in both groups, sugammadex was associated with a slightly better safety profile. Overall, sugammadex proved to be more effective and clinically advantageous than neostigmine for reversal of neuromuscular blockade**.**

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