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Original Article

Anaesthesia Section

Reversal of Rocuronium Induced Muscle Relaxation with Sugammadex versus Neostigmine in Patients undergoing General Anaesthesia: A Randomised Controlled Trial

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ABSTRACT

Introduction: Prolonged effects of neuromuscular blocking medications can lead to complications after surgery or the risk of Postoperative Residual Curarisation (PORC) in the postanaesthesia care unit, which may increase morbidity in surgical patients. To enhance patient safety and comfort, it is essential to completely reverse Neuromuscular Blockade (NMB) before transferring the patient to the Postanaesthesia Care Unit (PACU).

Aim: The aim of this study is to compare neostigmine with sugammadex for the reversal of rocuronium-induced muscle relaxation in patients undergoing general anaesthesia.

Materials and Methods: This randomised controlled study was conducted in patients undergoing general anaesthesia in Department of Anaesthesiology, Rohilkhand Medical College and Hospital, Bareilly, Uttar Pradesh, India, over a period of one year from 1st August 2023 to 31st July 2024. In this randomised controlled study, a total of 98 adult patients of either sex undergoing surgery under general anaesthesia were enrolled and assigned to two groups of 49 each. The patients were reversed with either of the drugs when the Train-of-Four (TOF) ratio reached 40%. group 1 received Inj. sugammadex 2 mg/kg intravenously (i.v), while group 2 received Inj. neostigmine 0.05 mg/kg with Inj. glycopyrrolate 0.01 mg/kg intravenously at the completion of surgery. Once the TOF stimulation reached 90%, the patient was extubated. The time taken to reach the TOF value from 40% to 90% was recorded. Patients were then transferred to the PACU, monitored for any adverse effects, and discharged from the PACU at an Aldrete score of ≥9 to the respective ward. Categorical data were analysed using the Chi-square test, while quantitative data were analysed using the Student t-test.

Results: A total of 98 adult patients were included in the present study. The demographic parameters (age, gender, weight, American Society of Anaesthesiologists (ASA) physical status I and II) were comparable between the two groups ($p>0.05$). The mean time taken to achieve TOF 40-90% was 2.29±1.12 minutes in group 1 and 8.72±1.5 minutes in group 2, respectively ($p<0.01$). In the study following extubation, none of the patients in either group exhibited any signs of PORC in the PACU. Significant changes in Heart Rate (HR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Mean Arterial Pressure (MAP) were observed post-extubation at 0, 5, and 10 minutes ($p<0.05$). group 1 had a lower incidence of postoperative nausea compared to group 2 ($p<0.05$).

Conclusion: The study concluded that sugammadex reverses rocuronium-induced muscle relaxation faster and more effectively, with fewer haemodynamic changes and adverse effects compared to the neostigmine-glycopyrrolate combination. Thus, its use can be advantageous in cases involving difficult airways, patients with respiratory co-morbidities, and those with limited myocardial reserve, where even a small increase in HR could be detrimental.

Keywords: Curarisation postoperative residual, Glycopyrrolate, Neuromuscular blockade, Neuromuscular monitoring

INTRODUCTION

General anaesthesia encompasses analgesia, amnesia, and muscle relaxation induced by neuromuscular blockers [1]. Muscle relaxation facilitates endotracheal intubation and allows operations in large body cavities, such as the abdomen and thorax, without requiring excessively deep anaesthesia [2]. For normal neuromuscular transmission, acetylcholine must bind to nicotinic cholinergic receptors on the motor end-plate. Non-depolarising muscle relaxants compete with acetylcholine for these binding sites. Rocuronium, a monoquaternary steroid analogue of vecuronium, is designed to provide a rapid onset of action [3]. It does not undergo any metabolism and is predominantly eliminated by the liver, with a small amount excreted by the kidneys. Renal disease does not significantly affect its duration of action. Rocuronium requires 0.45 to 0.9 mg/kg intravenously for intubation and 0.15 mg/kg boluses for maintenance. At doses of 0.9-1.2 mg/kg, its onset of action approaches that of succinylcholine (60-90 seconds). Thus, rocuronium serves as an effective alternative for rapid-sequence inductions, albeit with a substantially prolonged duration of action. Prolonged effects of neuromuscular blocking medications can lead to postoperative complications, such as persistent neuromuscular paralysis in the PACU, which may increase morbidity in surgical patients [4]. Unfortunately, laryngeal and pharyngeal muscle functions are typically among the last to be restored following muscle relaxation during general anaesthesia. Patients with PORC are also at risk of aspiration, hypoxia, pulmonary oedema, atelectasis, and pneumonia due to weakened laryngeal and pharyngeal reflexes [5].

To enhance patient safety and comfort, it is crucial to completely reverse NMB before transferring patients to the PACU. Anticholinesterase medications are often used in conjunction with muscarinic anticholinergic drugs to mitigate the side effects associated with muscle relaxants post-surgery. Neostigmine comprises a quaternary compound and a carbamate moiety [6]. The quaternary structure prevents it from crossing the blood-brain barrier, while acetylcholinesterase is covalently bonded to the carbamate moiety. Neostigmine (0.05 mg/kg) typically shows effects after five minutes, peaking at ten minutes and lasting for over an hour, with action time being prolonged in elderly patients. Sugammadex, a

novel selective relaxant-binding agent, is increasingly replacing neostigmine as the drug of choice for reversing non-depolarising NMB. Sugammadex, a modified gamma-cyclodextrin, is a special substance that selectively binds relaxants. Its three-dimensional structure resembles a doughnut, with a hydrophilic exterior and a hydrophobic cavity. The drug (such as rocuronium) is trapped within the cyclodextrin cavity through hydrophobic interactions, leading to the formation of a stable 1:1 guest-host complex that is water-soluble. This mechanism prevents the drug from interacting with nicotinic acetylcholine receptors and inducing a neuromuscular block in extracellular fluid. Sugammadex does not require co-administration with an antimuscarinic medication as it is generally excreted intact through the kidneys. Adverse reactions following sugammadex administration may include nausea, vomiting, headache, itching, procedural pain, and dysgeusia [7,8].

Neuromuscular monitors simplify the assessment of muscle paralysis. When it is necessary to utilise NMB to significantly enhance intubation quality and minimise airway damage, Neuromuscular Monitoring (NMT) serves as a useful guide [9]. Peripheral Nerve Stimulators (PNS) are employed for qualitative evaluation, which assesses the stimulated muscle's response either tactilely or visually. A standard PNS can utilise multiple nerve stimulation patterns, including Double Burst (DBS), Train of Four (TOF), tetanic, and Post-tetanic Count (PTC), allowing for an assessment of the Train-of-four Count (TOFC) and the degree of fade.

Most studies on this topic, such as those by Park ES et al., Paech MJ et al., and Kim NY et al., have employed qualitative methods to identify the reversals of neuromuscular blocking drugs, whereas we utilised the quantitative method of TOF ratio, which is the gold standard for measuring neuromuscular junction activities [8,10,11]. Few Indian studies, such as those by Sengar PK et al., and Singh S et al., have recorded only extubation parameters, while we documented perioperative haemodynamic parameters and observed patients in the PACU until discharge [12,13]. This study was conducted because sugammadex is a newer drug, and there are fewer studies regarding its use compared to neostigmine, as seen in authors such as Park ES et al., Illman HL et al., Mraovic B et al., Chang HC et al., Kizilay D et al., and Ledowski T et al., [8,14-18]. Therefore, the present study was designed as a randomised controlled trial to evaluate and compare the rapid and complete restoration of neuromuscular function between neostigmine and sugammadex, to determine the presence of PORC in both groups, to assess haemodynamic changes in both groups, and to document side effects after reversal in both groups.

MATERIALS AND METHODS

This randomised controlled study was conducted in patients undergoing general anaesthesia in the Department of Anaesthesiology, Rohilkhand Medical College and Hospital, Bareilly, Uttar Pradesh, India over a period of one year, from 1st August 2023 to 31st July 2024. This study was conducted after obtaining informed written consent from the patients and approval from the institutional ethics committee (vid. no. EC/NEW/INST/2022/UP/0197). The study was also registered with the Clinical Trials Registry of India (CTRI no. CTRI/2023/09/057991) and conforms to the CONSORT reporting guidelines and the principles of the Helsinki Declaration of 1975, revised in 2013.

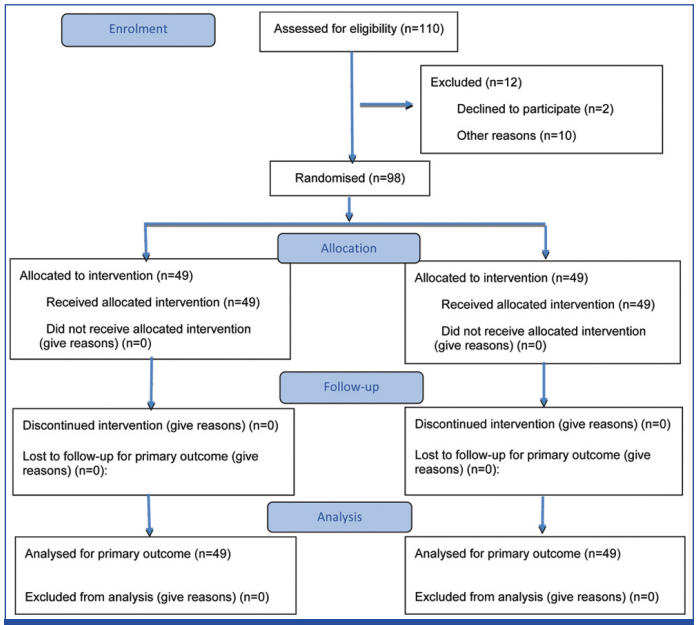
Sample size calculation: The sample size was calculated using the Power and Sample Size Program software, based on results obtained from a study by Fiorda Diaz J et al., involving similar groups, with an alpha of 5%, power of 70%, P0 of 22%, and P1 of 5% [19]. Here, P0 represents the proportion of outcomes in group 1, and P1 represents the proportion of outcomes in group 2. The calculated sample size amounted to 49 patients in each group.

Inclusion criteria: Patients aged 18 to 60 years with ASA physical status I and II undergoing elective surgeries under general anaesthesia were included in the study.

Exclusion criteria: Individuals with suspected difficult intubation, those with neuromuscular disorders, patients with known or suspected significant renal or hepatic dysfunction, allergies or contraindications to drugs affecting neuromuscular block or general anaesthesia, as well as pregnant or breastfeeding women were excluded. In total, 110 patients were assessed for eligibility, with 12 patients excluded for various reasons. Six patients received a regional epidural block, four were transferred to the ICU on a ventilator, and two refused consent to participate in the study. Consequently, 98 patients remained and were randomly allocated into two groups of 49 each, using computer-generated numbers.

Study Procedure

This double-blinded study was carried out after obtaining informed written consent from the patients one day prior to surgery. Patients were randomly divided in a 1:1 allocation ratio into two groups, each comprising 49 patients [Table/Fig-1]. Both the observer and the patient were blind to the study's details. The guide and co-guide allocated the patients into the two groups, maintained records, and administered the assigned drugs. The details of the drugs used were disclosed at the application of statistical tests.



[Table/Fig-1]: CONSORT 2025 flow diagram.
Flow diagram of the progress through the phases of a randomised trial of two groups (that is, enrolment, intervention allocation, follow-up, and data analysis)

Group 1 patients (n=49) received Inj. sugammadex at a dose of 2 mg/kg intravenously [20]. Group 2 patients received Inj. neostigmine at a dose of 0.05 mg/kg along with Inj. glycopyrrolate at a dose of 0.01 mg/kg intravenously [20].

A thorough pre-anaesthetic check-up was conducted one day prior to surgery. Before the procedure, the technique and protocols were explained, and the individuals were informed about follow-up until two hours after surgery. All patients in this study group were kept fasting according to the institutional protocol for eight hours prior to induction, regarding both solids and liquids. Patients were given oral tablet Alprazolam 0.25 mg and tablet Ranitidine 150 mg at bedtime and on the morning of the surgery at 6 AM, along with a sip of water. Baseline haemodynamic variables, including SBP, DBP, MAP, HR, and SpO_2 readings, were recorded in the pre-operative room, at induction, and at regular intervals of 15 minutes post-induction until the procedure was completed. Monitoring continued in the PACU at regular intervals of five minutes, 10 minutes, 30 minutes, 60 minutes, and 120 minutes.

Monitoring of neuromuscular function was conducted using kinemyography (KMG; GE Healthcare). The electrodes were placed

on the patient's skin surrounding the ulnar nerve after careful preparation. The kinemyography sensor was positioned over the tip of the thumb. The arm was oriented so that the motion of the thumb with the kinemyography was not restricted. Both groups received the same induction of general anaesthesia using this technique: patients were administered Inj. Midazolam at a dose of 0.02 mg/kg and Inj. Butorphanol at a dose of 0.02 mg/kg intravenously while preoxygenating with 100% oxygen. Following induction with Inj. Propofol at a dose of 2 mg/kg intravenously, supramaximal stimulation was performed on each patient using a neuromuscular monitor. This was followed by Inj. Rocuronium at a dose of 0.6 mg/kg intravenously, and the patient was ventilated with a bag and mask for three minutes using 100% oxygen. TOF measurements were recorded every 15 seconds. The patient was intubated when the TOF count displayed zero on the screen.

For the maintenance of anaesthesia, nitrous oxide and oxygen were administered in a ratio of 60:40, along with isoflurane. The mechanical ventilation of the patient's lungs was meticulously controlled (end-tidal CO_2 between 35 and 40 mmHg) to maintain normocapnia. Inj. Rocuronium (0.1 mg/kg intravenously) was used when two responses on TOF stimulation were displayed on the screen in order to maintain relaxation. Isoflurane was discontinued 30 minutes prior to the end of surgery, and Inj. Ondansetron at a dose of 4 mg intravenously was given. Nitrous oxide was stopped upon completion of the surgery, and patients were reversed with either drug when the TOF ratio reached 40%. Once the TOF stimulation reached 90%, the patient was extubated following thorough suctioning. The time taken to reach a TOF value from 40% to 90% was recorded.

After extubation, patients were transferred to the PACU, where the level of PORC and postoperative discomfort were evaluated at five, 10, 15, 30, 60, and 120 minutes using clinical assessments such as level of consciousness, normal regular breathing, a five-second head lift test, and compliance with commands like eye opening and tongue protrusion, as well as oxygen desaturation of less than 90%. Patients received oxygen supplementation at a rate of 6 L/min for the first 30 minutes in the PACU and were then placed on room air if the SpO_2 level was above 93%. All individuals were assessed using the Aldrete score [21] before being discharged from the PACU after two hours, and the scores were recorded. Patients were monitored for adverse effects such as nausea, vomiting, odynophagia, pyrexia, fatigue, abdominal pain, hypotension, headache, dizziness, confusion, diplopia, shivering, and throat pain.

STATISTICAL ANALYSIS

Categorical data were analysed using the Chi-square test, while quantitative data were assessed using the unpaired t-test, employing Statistical Package for Social Sciences (SPSS) version 23. The p-value was considered insignificant when greater than 0.05 (p-value >0.05). A p-value of less than 0.05 (p-value <0.05) was regarded as significant, and a p-value of less than 0.01 (p-value <0.01) was deemed highly significant.

RESULTS

In the study, 110 patients were assessed for eligibility. Twelve patients were excluded for various reasons. A regional epidural block was administered to six patients; four patients were transferred to the ICU on ventilators, and two refused to provide consent to participate in the study. Consequently, the remaining 98 patients were randomly allocated into two groups of 49 each using computer-generated numbers [Table/Fig-1].

The demographic parameters (age, gender, weight, and ASA physical status I and II) were comparable between the two groups (p-value >0.05) [Table/Fig-2]. In this study, the time taken to reach a TOF value from 40% to 90% in group 1 was (2.29±1.12) minutes, while in group 2 it was (8.72±1.5) minutes, with p-value <0.01, which was statistically significant. Additionally, all patients were adequately reversed; hence, other clinical signs such as eye opening, a five-second head lift, normal regular breathing, and tongue protrusion were observed equally in all patients in both groups. The Aldrete Score was measured at two hours before discharge from the PACU to their respective wards and was found to be ≥9 for both groups (p=1.000) [Table/Fig-3].

Parameters	Group 1 (n=49) Mean±SD	Group 2 (n=49) Mean±SD	p-value
Age (years)	41.04±11.1	38.69±12.16	0.322
Weight (Kg)	51.3±6.1	53.7±8.5	0.116
Male	17 (34.7%)	23 (46.9%)	0.218
Female	32 (65.3%)	26 (53.1)	
ASA I	29 (59.2%)	24 (49.0%)	0.311
ASA II	20 (40.8%)	25 (51.0%)	

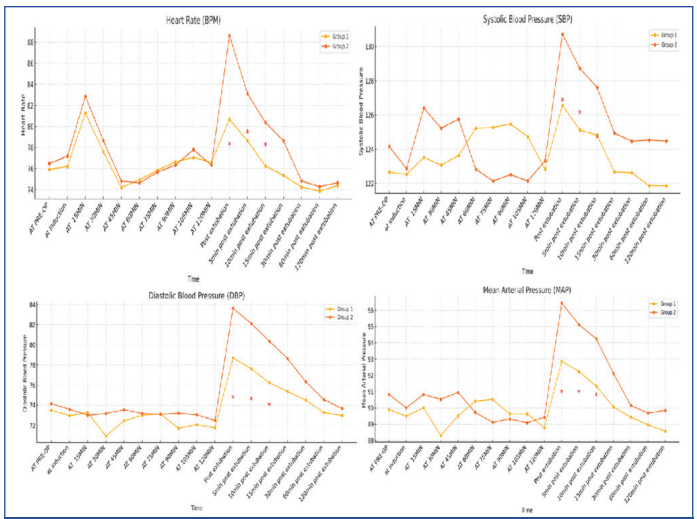
[Table/Fig-2]: Demographic profile of the two groups.

Parameters	Group 1 (n=49) Mean±SD	Group 2 (n=49) Mean±SD	p-value
Time taken from TOF 0.4 to 0.9 (min)	2.29±1.12	8.72±1.5	p<0.01
Modified Aldrete Score at 2 hours in PACU	10.0±0.0	10.0±0.0	1.000

[Table/Fig-3]: Comparison of parameters between group 1 and group 2.

In this study, it was found that the baseline Heart Rate (HR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), and Mean Arterial Pressure (MAP) between group 1 and group 2 were comparable. A significant change was noted post-extubation at zero minutes, five minutes, and ten minutes post-extubation in HR, SBP, DBP, and MAP (p-value <0.05) [Table/Fig-4]. A significant change in HR was observed after administering the reversal drug post-extubation, at five minutes post-extubation, and at ten minutes post-extubation, with p-values of 0.001, 0.002, and 0.005 in Groups 1 and 2, indicating that the results are statistically significant. Statistically significant changes in SBP, DBP, and MAP were noted post-extubation (p-value <0.001) between Groups 1 and 2. Similarly, statistically significant changes in SBP, DBP, and MAP were observed five minutes post-extubation and ten minutes post-extubation, with p-values of (0.001, 0.002, 0.0001) and (0.013, 0.005, 0.001) between Groups 1 and 2, respectively. No significant change in SpO_2 readings was observed at different intervals throughout the course of the surgery and in the PACU between group 1 and group 2 (p-value >0.05) [Table/Fig-5].

In this study, fifty-three patients experienced one or more adverse events: 18 patients in group 1 and 35 patients in group 2. None of the patients in either group had pyrexia, fatigue, diplopia, hypotension, or abdominal pain (p-value >0.05) [Table/Fig-6].



[Table/Fig-4]: Bar diagram showing haemodynamic changes at different intervals between group 1 and group 2.

SpO_2	Group 1 Mean±SD	Group 2 Mean±SD	p-value
At pre-op	97.65±0.80	97.76±0.95	0.567
At induction	98.33±0.94	98.0±0.68	0.052
At 15 min	99.16±0.83	98.82±0.73	0.060
At 30 min	99.43±0.71	99.12±0.67	0.083
At 45 min	98.65±0.88	98.76±0.88	0.567
At 60 min	98.2±0.87	98.16±0.59	0.786
At 75 min	97.94±0.59	98.14±0.58	0.087
At 90 min	97.94±0.59	97.98±0.72	0.760
At 105 min	97.65±0.72	97.76±0.52	0.425
AT 120 min	97.82±0.75	97.88±0.63	0.665
Post-extubation*	97.82±0.75	97.92±0.67	0.481
5 min post-extubation*	99.27±0.57	98.9±0.74	0.077
10 min post-extubation*	98.90±0.74	98.94±0.97	0.815
15 min post-extubation*	98.65±0.88	98.76±0.88	0.567
30 min post-extubation*	99.22±0.56	98.86±0.76	0.078
60 min post-extubation	98.86±0.72	98.92±0.98	0.812
120 min post-extubation	98.68±0.86	98.78±0.84	0.568

[Table/Fig-5]: Comparison of mean SpO_2 at the different time intervals in between group 1 and group 2.

Adverse effects	Group 1 N=49 Number (%)	Group 2 Number (%)	p-value
Nausea	5 (10.2)	13 (26.5)	0.036
Vomiting	1 (2)	3 (6.1)	0.307
Odynophagia	3 (6.1)	4 (8.2)	0.694
Headache	3 (6.1)	4 (8.2)	0.694
Dizziness	1 (2)	1 (2)	1.000
Confusion	1 (2)	4 (8.2)	0.168
Shivering	4 (8.2)	4 (8.2)	1.000
Throat pain	0	2 (4.1)	0.153

[Table/Fig-6]: Comparison of adverse effects in group 1 and group 2.

DISCUSSION

In general anaesthesia, muscle relaxants are used to aid in endotracheal intubation and to provide optimal surgical conditions by reducing abdominal muscle tone, particularly in minimally invasive laparoscopic procedures [15]. Compared to anaesthetic approaches that do not employ Neuromuscular Blocking Agents (NMBAs), the use of NMBAs is still associated with greater morbidity and mortality, despite the fact that their usage has significantly decreased the incidence of laryngopharyngeal lesions caused by tracheal intubation [22]. When a reversal agent is administered inappropriately, such as insufficiently or without the assistance of a neuromuscular monitor, the result is inadequate reversal [23]. PORC leads to many of the respiratory complications observed in the PACU following the use of intermediate-acting NMBAs [24]. The incidence of residual neuromuscular blockade, as reported in the Residual Curarisation and its Incidence at Tracheal Extubation (RECITE) trial, is 63.5% (95% confidence interval, 57.4-69.6%) at tracheal extubation and 56.5% (95% confidence interval, 49.8% - 63.3%) upon arrival at the PACU [25]. Various methods have been advocated to reduce these complications, including the use of Total Intravenous Anaesthesia (TIVA) without muscle relaxation, Neuromuscular Transmission (NMT) monitoring, and the use of sugammadex for the reversal of muscular blockade [26].

Over the last sixty years, the most commonly used reversal medications have been those that inhibit acetylcholinesterase, such as neostigmine. Neostigmine acts by competitive antagonism to reverse the effects of medications that block non-depolarising neuromuscular transmission [27]. However, the reversal may be limited and unexpected due to its indirect mechanism of action, which could lead to a risk of PORC [27].

Sugammadex, a novel reversal agent for aminosteroid muscle relaxants, particularly rocuronium, is now available in most countries worldwide [27]. Due to its direct mechanism of action, sugammadex is associated with the rapid and reliable reversal of any level of blockade. Additionally, the negative side effects of antimuscarinic medications and neostigmine are avoided. The primary aim of this study was to compare the rapid and complete restoration of neuromuscular function between neostigmine and sugammadex. Secondary objectives included determining the incidence of PORC in both groups, assessing haemodynamic changes in both groups, and documenting side effects following reversal in both groups.

The demographic profile, including age, weight, gender, and ASA grades, was compared between the two groups. All the demographic variables were statistically insignificant (p-value >0.05).

The main efficacy variable was the comparison of rapid recovery between both groups. Rapid recovery was measured by the time (in minutes) starting from the administration of the study drug, i.e., at a TOF ratio of 0.4, to the recovery of the TOF ratio to greater than or equal to 0.9. In this study, as shown in [Table/Fig-3], the time taken to reach a TOF ratio of 0.9 from 0.4 was faster in group 1 compared to group 2. This finding is consistent with a study conducted by Khuenl-Brady KS et al., who reported that when using sugammadex instead of neostigmine, the mean time to recover a TOF ratio of 0.9 was substantially faster (2.7 minutes versus 17.9 minutes, respectively, with p-value <0.0001); these results were statistically significant [28]. Similar results were observed in a trial conducted by Gaszynski T et al., [5], where they found that for the groups using sugammadex and neostigmine, the mean time to reach 90% TOF was 2.7 minutes versus 9.6 minutes, respectively, with p-value <0.05, indicating statistical significance. Additionally, results akin to our study were reported in a trial by Lemmens HJM et al., who discovered that when sugammadex (4.5 minutes) was used, the geometric mean time for recovering a 0.9 train-of-four ratio was fifteen times faster compared to neostigmine (66.2 minutes) with a p-value of <0.0001, demonstrating statistical significance [29]. Furthermore, Illman HL et al., observed that the durations between the reversal with neostigmine and sugammadex to achieve a TOF ratio of 0.90 were 13.3±5.7 minutes and 1.7±0.7 minutes, respectively, with p-value <0.001, suggesting statistically significant results [14].

The secondary objective included the number of patients who experienced PORC. Once the reversal drug was administered, all patients were adequately reversed; thus, other clinical signs such as eye opening, a five-second head lift, normal regular breathing, and tongue protrusion were exhibited equally by all patients in both groups. The Aldrete Score was measured two hours before discharge from the PACU to their respective wards and was found to be ≥9 for both groups (p=1.000) [Table/Fig-3,5]. This indicates that following extubation and during their stay in the PACU, no patients in either group displayed any signs of PORC. In agreement with this study, Lemmens HJM et al., stated that, considering the limitations in the analysis of mild residual paralysis or recurrence of the block in awake patients, they found no evidence of residual paralysis or recurrence of the block in any patient [29]. Similar results were observed in a trial conducted by Khuenl-Brady KS et al., who noted that there was no clinically evident residual neuromuscular blockade following reversal with either sugammadex or neostigmine, and there was no clinical indication of any remaining neuromuscular blockade [28]. Comparable findings were reported by Mraovic B et al., who discovered that following the administration of neuromuscular blockade reversal, the sugammadex group recovered in the Operating Room (OR)

significantly faster (regarding extubation, obeying verbal instructions, eye opening, and time to exit from the OR) [15]. Recovery times during the postoperative period did not differ, nor did the length of stay in the PACU or the time to the first ambulation, and these differences were not statistically significant.

Another objective was to compare the haemodynamic changes between the two groups, whereby significant changes in Heart Rate (HR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), and Mean Arterial Pressure (MAP) were noted post-extubation, five minutes after extubation, and ten minutes after extubation between group 1 and group 2. This indicates that, compared to group 2, group 1 was more haemodynamically stable, as there were few to no changes in haemodynamic variables following extubation [Table/Fig-4]. Similar findings were reported in a trial conducted by Khuenl-Brady KS et al., who observed that sugammadex might have fewer haemodynamic side effects in comparison to neostigmine [28]. While the mean SBP course was identical for both groups, neostigmine caused a greater increase in mean DBP at two minutes after the dose than sugammadex, as well as in mean HR at two and five minutes post-dose. Comparable results were noted by Chang HC et al., who observed that at all time points, the sugammadex group exhibited a significantly lower HR and MAP than the neostigmine/glycopyrrolate group (p-value <0.05) [16]. Similar to our results, a study conducted by Park ES et al., found that the incidence of tachycardia in the PACU was significantly lower in the sugammadex group (8.0%) than in the pyridostigmine group (17.3%) with p-value ≤0.001, indicating the results were statistically significant [8]. A study by Kizilay D et al., also showed that the sugammadex group had a significantly decreased HR one minute after the medication (p-value <0.05) while the neostigmine group exhibited a rise in HR and SBP during postoperative measures, continuing three minutes after the drug was administered, with p-value <0.05 indicating statistically significant results [17].

Another objective was to document the side effects observed between the two groups. In this study, it was noted that group 1 had lower incidences of postoperative nausea compared to group 2 [Table/Fig-6]. This finding aligns with a study conducted by Khuenl-Brady KS et al., who reported that the neostigmine group experienced a slightly higher frequency of adverse events than the sugammadex group [28]. In agreement with this study, Lemmens HJM et al., found that, in total, 20% of patients treated with sugammadex and 28% of patients treated with neostigmine experienced adverse effects, concluding that sugammadex was much better tolerated than neostigmine [29]. Similar results were observed in a trial conducted by Ledowski T et al., who found that the requirements for antiemetic medication in the PACU showed a significant difference between sugammadex and non-sugammadex patients (SUG 13.6% vs. NON-SUG 18.2%; p-value <0.05) [18]. This difference was mainly attributed to the higher rate of Postoperative Nausea and Vomiting (PONV) in the neostigmine-reversed patients in the non-sugammadex group.

Limitation(s)

The study included only ASA grades I and II patients, which limits the generalisability of the findings to patients with different ASA grades. The sample size of the study was 98 patients, which, although statistically calculated, may restrict the ability to detect rare side effects or subtle differences in outcomes. The patients in this study were within the weight range of 45–75 kg, thereby limiting the ability to assess the effects of the drug in morbidly obese patients. Additionally, the study included patients aged 18 to 60 years, which restricts the generalisability of the findings to patients from different age groups. The methodology focused on immediate and intermediate recovery parameters but did not include long-term outcomes, such as postoperative complications or patient satisfaction, which could provide a more comprehensive evaluation. The incidence of PORC was lower in this study because patients were reversed based on the TOF ratio rather than clinical signs. Consequently, recovery was complete in both groups; however, in routine practice, TOF monitors are not readily available, so patients are typically reversed based on clinical assessments.

CONCLUSION(S)

Sugammadex, as a Neuromuscular Blockade (NMB) reversal agent, is a more efficient drug than neostigmine, with fewer haemodynamic changes and reduced adverse effects in the perioperative period. Due to its unique pharmacodynamics, which involve the encapsulation of the rocuronium molecule for elimination, the reversal it provides is superior and does not require the concurrent use of glycopyrrolate. Additionally, it can be advocated for use in patients with difficult airways, respiratory co-morbidities, and those with poor myocardial reserve, where a small increase in heart rate due to glycopyrrolate could be detrimental.

REFERENCES

[1] Ilies C, Gruenewald M, Ludwigs J, Thee C, Höcker J, Hanss R, et al. Evaluation of the surgical stress index during spinal and general anaesthesia. Br J Anaesth. 2010;105(4):533-37.
[2] Moon HY, Baek CW, Kim JS, Koo GH, Kim JY, Woo YC, et al. The causes of difficult tracheal intubation and preoperative assessments in different age groups. Korean J Anesthesiol. 2013;64(4):308-14.
[3] Parasa M, Vemuri NN, Shaik MS. Comparison of equipotent doses of rocuronium and vecuronium. Anesth Essays Res. 2015;9(1):88-91.
[4] Geldner G, Niskanen M, Laurila P, Mizikov V, Hübler M, Beck G, et al. A randomised controlled trial comparing sugammadex and neostigmine at different depths of neuromuscular blockade in patients undergoing laparoscopic surgery. Anaesthesia. 2012;67(9):991-98.
[5] Gaszynski T, Szewczyk T, Gaszynski W. Randomized comparison of sugammadex and neostigmine for reversal of rocuronium-induced muscle relaxation in morbidly obese undergoing general anaesthesia. Br J Anaesth. 2012;108(2):236-39.
[6] Wu X, Oerding H, Liu J, Vanacker B, Yao S, Dahl V, et al. Rocuronium blockade reversal with sugammadex vs. neostigmine: Randomized study in Chinese and Caucasian subjects. BMC Anesthesiol. 2014;14(1):01-10.
[7] Abad-Gurumeta A, Ripollés-Melchor J, Casans-Francés R, Espinosa A, Martínez-Hurtado E, Fernández-Pérez C, et al. Evidence Anaesthesia Review Group. A systematic review of sugammadex vs neostigmine for reversal of neuromuscular blockade. Anaesthesia. 2015;70(12):1441-52.
[8] Park ES, Lim BG, Lee WJ, Lee IO. Sugammadex facilitates early recovery after surgery even in the absence of neuromuscular monitoring in patients undergoing laryngeal microsurgery: A single-center retrospective study. BMC Anesthesiol. 2015;16:01-07.
[9] Duţu M, Ivaşcu R, Tudorache O, Morlova D, Stanca A, Negoiţă S, et al. Neuromuscular monitoring: An update. Rom J Anaesth Intensive Care. 2018;25(1):55-60.
[10] Paech MJ, Kaye R, Baber C, Nathan EA. Recovery characteristics of patients receiving either sugammadex or neostigmine and glycopyrrolate for reversal of neuromuscular block: A randomised controlled trial. Anaesthesia. 2018;73(3):340-47.
[11] Kim NY, Koh JC, Lee KY, Kim SS, Hong JH, Nam HJ, et al. Influence of reversal of neuromuscular blockade with sugammadex or neostigmine on postoperative quality of recovery following a single bolus dose of rocuronium: A prospective, randomized, double-blinded, controlled study. J Clin Anesth. 2019;57:97-102.
[12] Sengar PK, Kumar M. A systematic evaluation and economic assessment of sugammadex in general anaesthesia for muscle relaxation reversal: A prospective cross-sectional study. Student's Journal of Health Research Africa. 2024;5(3):07.
[13] Singh S, Jain A, Saini P. Comparison of incidence of residual blockade in Post Anaesthetic Care Unit (PACU) & quality of reversal of neuromuscular blockade with sugammadex vs neostigmine. Int J Life Sci Biotechnol Pharma Res. 2025;14(5):1250-55.
[14] Illman HL, Laurila P, Antila H, Meretoja OA, Alahuhta S, Olkkola KT. The duration of residual neuromuscular block after administration of neostigmine or sugammadex at two visible twitches during train-of-four monitoring. Anesth Analg. 2011;112(1):63-68.
[15] Mraovic B, Timko NJ, Choma TJ. Comparison of recovery after sugammadex or neostigmine reversal of rocuronium in geriatric patients undergoing spine surgery: A randomized controlled trial. Croat Med J. 2021;62(6):606-13.
[16] Chang HC, Liu SY, Lee MJ, Lee SO, Wong CS. Sugammadex reversal of muscle relaxant blockade provided less post-anesthesia care unit adverse effects than neostigmine/glycopyrrolate. J Formos Med Assoc. 2022;121(12):2639-43.
[17] Kizilay D, Dal D, Saracoglu KT, Eti Z, Gogus FY. Comparison of neostigmine and sugammadex for hemodynamic parameters in cardiac patients undergoing noncardiac surgery. J Clin Anesth. 2016;28:30-35.
[18] Ledowski T, Falke L, Johnston F, Gillies E, Greenaway M, De Mel A, et al. Retrospective investigation of postoperative outcome after reversal of residual neuromuscular blockade: Sugammadex, neostigmine or no reversal. Eur J Anaesthesiol. 2014;31(8):423-29.

[19] Fiorda Diaz J, Echeverria-Villalobos M, Esparza Gutierrez A, Dada O, Stoicea N, Ackermann W, et al. Sugammadex versus neostigmine for neuromuscular blockade reversal in outpatient surgeries: A randomized controlled trial to evaluate efficacy and associated healthcare cost in an academic center. Front Med (Lausanne). 2022;9:1072711.
[20] 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(10):874-81.
[21] Ding D, Ishag S. Aldrete scoring system. InStatPearls [Internet]. 2023. StatPearls Publishing.
[22] de Boer HD, Driessen JJ, Marcus MA, Kerkkamp H, Heeringa M, Klimek M. Reversal of rocuronium-induced (1.2 mg/kg) profound neuromuscular block by sugammadex: A multicenter, dose-finding and safety study. Anesthesiology. 2007;107(2):239-44.
[23] Honing GH, Martini CH, Bom A, Van Velzen M, Niesters M, Aarts LP, et al. Safety of sugammadex for reversal of neuromuscular block. Expert Opin Drug Saf. 2019;18(10):883-91.
[24] Butterly A, Bittner EA, George E, Sandberg WS, Eikermann M, Schmidt U. Postoperative residual curarization from intermediate-acting neuromuscular blocking agents delays recovery room discharge. Br J Anaesth. 2010;105(3):304-09.
[25] Fortier LP, McKeen D, Turner K, de Médicis É, Warriner B, Jones PM, et al. The RECITE study: A Canadian prospective, multicenter study of the incidence and severity of residual neuromuscular blockade. Anesth Analg. 2015;121(2):366-72.
[26] Carvalho H, Verdonck M, Cools W, Geerts L, Forget P, Poelaert J. Forty years of neuromuscular monitoring and postoperative residual curarisation: A meta-analysis and evaluation of confidence in network meta-analysis. Br J Anaesth. 2020;125(4):466-82.
[27] 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(5):631-41.
[28] Khuenl-Brady KS, Wattwil M, Vanacker BF, Lora-Tamayo JI, Rietbergen H, Alvarez-Gómez JA. Sugammadex provides faster reversal of vecuronium-induced neuromuscular blockade compared with neostigmine: A multicenter, randomized, controlled trial. Anesth Analg. 2010;110(1):64-73.
[29] Lemmens HJ, El-Orbany MI, Berry J, Morte JB, Martin G. Reversal of profound vecuronium-induced neuromuscular block under sevoflurane anesthesia: Sugammadex versus neostigmine. BMC Anesthesiol. 2010;10:15.

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