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

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

International Journal of Current Pharmaceutical Review and Research 2025; 17(11); 1238-1244

Original Research Article

Comparative Evaluation of Sugammadex and Neostigmine As Reversal Agent for Spine Surgery in Adult Patients: A Randomised Double-Blind Study

Khemraj Meena[1], Aman Azad[2], Pramila Soni[3], Santosh Choudhary[4], Sandeep Sharma[5], Usha Rani[6]

[1]Senior Professor, Department of Anaesthesiology, RNT Medical College, Udaipur, Rajasthan, India
[2]Senior Resident, Department of Anaesthesiology, PIMS, Udaipur, Rajasthan, India
[3]Assistant Professor, Department of Anaesthesiology, Government Medical College, Pali, Rajasthan, India
[4]Associate Professor, Department of Anaesthesiology, RNT Medical College, Udaipur, Rajasthan, India
[5]Professor, Department of Anaesthesiology, RNT Medical College, Udaipur, Rajasthan, India
[6]PG Resident, Department of Anaesthesiology, RNT Medical College, Udaipur, Rajasthan, India

Received: 25-09-2025 / Revised: 23-10-2025 / Accepted: 25-11-2025
Corresponding Author: Dr. Aman Azad
Conflict of interest: Nil

Abstract:

Background & Aims: Neuromuscular blockade (NMB) is a crucial component of general endotracheal anaesthesia in spine surgery and incomplete recovery may lead to postoperative complications. Neostigmine, a traditional NMB reversal agent can have unpredictable effects and adverse events. Sugammadex, a novel γ-cyclodextrin, offers a faster and more predictable reversal of steroidal nondepolarizing neuromuscular blocking agent (NMBA), potentially reducing adverse outcomes. This study aimed to compare the efficacy and safety of sugammadex versus neostigmine in reversing rocuronium-induced NMB in patients undergoing elective spine surgeries.

Methods: A prospective, randomized, double-blind study was conducted on 62 ASA Grade I-II adult patients aged 18-60years of either gender undergoing elective spine surgeries. Patients were randomly assigned to receive either sugammadex (4 mg/kg) or neostigmine (0.05 mg/kg) with glycopyrrolate (0.008 mg/kg) for NMB reversal. Primary outcome measured was time to achieve train of four (TOF) ratio>0.9. Secondary outcomes included time to spontaneous breathing, time to respond to verbal commands, extubation time, total duration of anaesthesia, hemodynamic parameters, emergence agitation score and surgeon satisfaction score.

Results: Sugammadex significantly reduced the time to achieve TOF>0.9, spontaneous breathing, verbal response and extubation compared to neostigmine ($p<0.001$). Total anaesthesia duration was shorter in the sugammadex group ($p=0.0386$). Blood pressure was comparable between the groups but heart rate patterns differed in post-reversal time. Complications were minimal and non-life-threatening in both groups.

Conclusions: Sugammadex demonstrated superior efficacy and faster recovery compared to neostigmine in reversing rocuronium-induced neuromuscular blockade in spine surgeries with stable haemodynamics and a favourable safety profile. It presents a preferable option for NMB reversal.

Keywords: Sugammadex, Neostigmine, Rocuronium, Neuromuscular Blockade, Spine Surgery.

Introduction

Neuromuscular blockade (NMB) is an essential component of general endotracheal anaesthesia (GETA) for performing a variety of surgical procedures. Spine surgeries are one of the common surgeries performed on a routine basis and neuromuscular blocking agents (NMBA) are commonly administered for optimising operative state [1] Rocuronium bromide is frequently used NMBA for muscle relaxation during anaesthesia. It has a faster onset time than any other nondepolarising NMBA. Deep muscle relaxation is required intraoperatively to prevent coughing, bucking and accidental extubation. Fast, complete and dependable reversal of NMB is essential to enhance patient wellbeing and comfort. Many a times, patients do not achieve adequate neuromuscular recovery prior to extubation, risking postoperative residual blockade, airway obstruction, pulmonary complications [2] which may result in significant morbidity and prolonged hospital stay [3,4,5].

Acetylcholinesterase inhibitors like neostigmine, a traditional NMBA reversal agent, increase acetylcholine concentration to nullify effect of non-depolarizing neuromuscular blockers at neuromuscular junction receptors. Sugammadex, a modified γ-cyclodextrin, has been newly introduced as asteroidal NMBA binder drug in our part of world. It has a high affinity for steroidal non-depolarizing NMBA and forms a compact bond with unbound molecules, rendering them chemically inactive and preventing their action at the neuromuscular junction [6,7]. Sugammadex provides faster and more predictable reversal of block while avoiding the side effects associated with neostigmine and antimuscarinic drugs, the latter being coadministered with the acetylcholinesterase inhibitors. [8,9,10,11]

There is paucity of literature analyzing the reversal characteristics and haemodynamic effects of sugammadex and neostigmine in patients undergoing spine surgeries. [12] There is also a practical knowledge gap on the effect of sugammadex on Indian population undergoing spine surgeries. Therefore, we planned this study to compare sugammadex and neostigmine as reversal agents after rocuronium use in patients undergoing elective spine surgeries with primary objective to compare the duration from the injection of reversal agent to achieving of train of four (TOF) ratio to 90% and secondary objectives to compare the time to return of spontaneous breathing and responsiveness to verbal commands, haemodynamic parameters, duration of anaesthesia, duration of surgery, surgeon's satisfaction score, emergence agitation score and side effects.

Materials and Methods

After obtaining approval from the institutional ethical committee (RNT/ACAD/IEC/2023/660) and registering in the Clinical Trials Registry India (CTRI/2024/02/062776), this prospective, randomized, double-blind, comparative, clinical study was conducted on patients undergoing spine surgeries under GETA from March 2024 to August 2024 after informed and written consent from all participants.

Sixty-two ASA physical Grade I and II aged between 18-60 years of either gender undergoing elective spine surgeries under GETA were incorporated in the study. Patients with any neuromuscular disorder, renal dysfunction, history of general anaesthesia exposure in the 7 days preceding the study, allergy to any drugs used in the study, pregnant and breast-feeding mothers were excluded from the study

Sample size was calculated on the basis of previous study by Ghoneim AA et al [13] in which at 80% study power and an alpha error of 5%, to detect a difference of 5 min in reversal time between the groups, 28 patients were required in each group. To compensate for the dropouts, 31 patients were included in each group.

The study population was randomly designated into two groups using a computer-generated table of random numbers. Group allocation concealment was done using opaque sealed envelope sequentially numbered technique. Group S (n=31) received inj sugammadex 4mg/kg diluted up to 10 ml volume. Group N (n=31) received inj neostigmine 0.05mg/kg combined with glycopyrrolate 0.008 mg/kg dose diluted upto 10 ml volume.

To ensure double blinding, study drug infusion was prepared by an independent anaesthesiologist who didnot participated further in the study. Another anaesthesiologist administered study drug and recorded the study parameters. Both the patient and the administering anaesthesiologist were blinded to the group allocation.

Pre-anaesthetic evaluation was conducted the day before surgery to assess the general condition of the patient with all relevant routine investigations. After thorough assessment, written informed consent was obtained. All patients were kept fasted for at least 6 hours before surgery. After reaching to operating room, all patients were premedicated with inj midazolam 1 mg intravenously (IV) through a previously secured 20 G cannula. They were preoxygenated with 100% oxygen for 3 min. Non-invasive monitoring, incorporated into anaesthesia workstation (Carescape®, GE Healthcare, Helsinki, Finland) was applied. This included pulse oximetry (SpO2), electrocardiography (ECG), non-invasive blood pressure (NIBP), axillary temperature probe, neuromuscular monitoring (NMT), bispectral monitoring (BIS). Anaesthesia was induced using inj propofol (2 mg/kg), inj fentanyl (2 µg/kg) and inj rocuronium bromide (0.6 mg/kg) IV to facilitate endotracheal intubation after TOF stimulation reached 0-1. Patients were mechanically ventilated using low flow air-oxygenmixture (50:50) using the anaesthesia workstation (Datex-Ohmeda®, Ohmeda, Madison, USA). Tidal volume was set at 8 ml/kg and respiratory rate was adjusted to maintain an end-tidal CO2 (EtCO2) between 30-35 mmHg. Muscle relaxation was monitored throughout anaesthesia by peripheral nerve stimulator (Carescape®, GE Healthcare, Helsinki, Finland) applied to the adductor pollicis. Anaesthesia was maintained using infusion of inj fentanyl 0.5 µg/kg/hr and inj rocuronium bromide 0.4 mg/kg/hr to maintain TOF of 0-1. If TOF at any time was >1, additional dose of 0.1 mg/kg of rocuronium was administered. Sevoflurane inhalation was administered at 1 minimum alveolar concentration (MAC) and subsequently adjusted to

maintain mean arterial blood pressure (MAP) and heart rate (HR) within 20% of pre-anaesthesia levels. At the end of surgery, after skin closure, the flow of inhalational anaesthetic agent was ceased. When the TOF count reached 2, residual muscle relaxation was antagonized with inj neostigmine 0.04 mg/kg IV and inj glycopyrrolate 0.008mg/kg IV or with inj sugammadex 4 mg/kg IV as per the group allocation. Perioperative vital signs were recorded. Primary outcome measured was time to achieve TOF >0.9 whereas secondary outcomes measured were total duration of surgery (defined as time from incision till last suture placement), total duration of anaesthesia (defined as time from induction till extubation), time to spontaneous breathing (defined as time when patient began to generate adequate tidal volume that is >5ml/kg), time to respond to verbal command were recorded along with haemodynamic parameters at 1 min intervals until 10 minutes then at 15,20,25 and 30 min. Incidence of hypotension/hypertension or bradycardia/tachycardia were also recorded. Emergence agitation score (14) [1 = Sleeping, 2 = Awake and calm, 3 = Irritable and crying, 4 = Inconsolable crying, 5 = Severe restlessness and disorientation] and Surgeon Satisfaction score [I - Very Satisfied, II – Satisfied, III - Not Satisfied] were also recorded 5 min after endotracheal extubation.

Results obtained in the study were entered into Microsoft Excel and analyzed using SPSS 25 software. Continuous variables were presented as mean±SD and compared using Student's t-test. Categorical data were presented as number (proportion) and compared with chi-square test. $p<0.05$ was considered statistically significant.

Results

80 patients were evaluated for eligibility out of which 18 were excluded, 10due to not meeting inclusion criteria and 8 patients refused to participate. A total of 62 patients were registered in the study (Fig 1). Both the groups were comparable with respect to age, gender, weight, height, ASA status, type of surgery and duration of surgery (Table-1).

Total duration of anaesthesia was significantly lesser in group S (247.2 ± 46.1min) as compared to group N (272.8 ± 62.9min) (p=0.039). The time taken for return of spontaneous breathing was less in Group S (53.32 ± 29.13sec) as compared to Group N (607.74 ± 257.16sec)(p=0.00001).The time taken for responding to verbal command was less in Group S (76.58 ± 31.47 sec) as compared to Group N (724.74 ± 262.03sec)(p=0.00001).The time taken for extubation was less in Group S (102.87 ± 38.17sec)as compared to Group N (887.70 ± 252.24sec) (p=0.00001).

Postoperatively, statistically significant higher heart rates immediately post-reversal and at 1 minute were reported in sugammadex group while the neostigmine group showed elevated heart rates at 8, 9, 10, 15, 20, and 25 minutes post-reversal (Fig2).SBP, DBP and MAP were comparable between both the groups at all measured time intervals (Fig 3).There were no incidence of hypotension or hypertension or bradycardia in any of the patients in both the groups.

Emergence agitation score was comparable between both the groups(p=0.154). Postextubation, surgeons were more satisfied with Group S when compared to group N (p=0.0268) (Table-3).

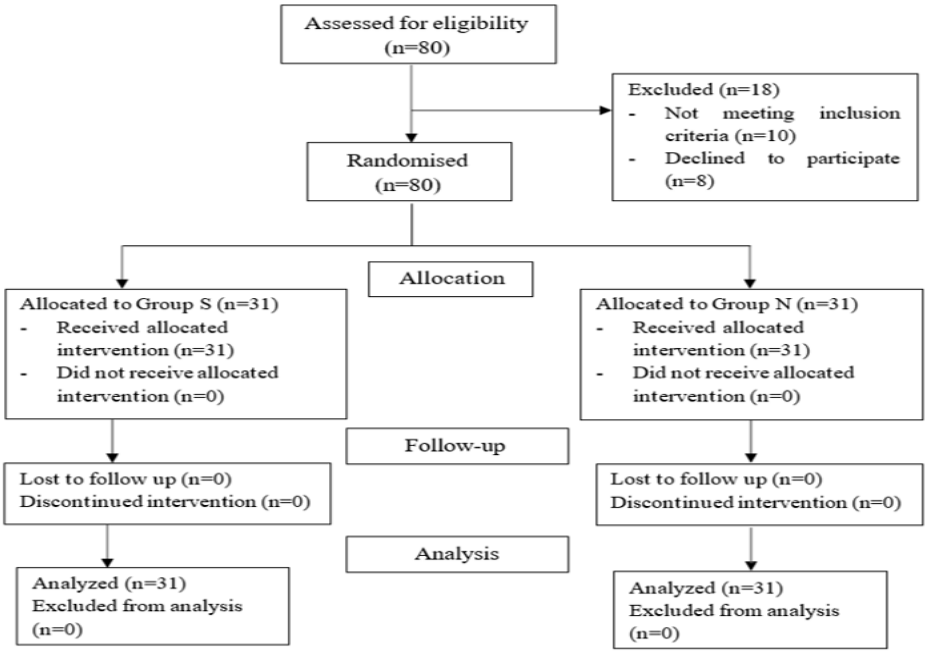

Figure 1: Consort diagram

Table 1: Demographic profile, type of surgery and duration of surgery of study population

Parameters		**Group N (n=31)**	**Group S (n=31)**	**p value**
Age (years)		43.2 ± 11.8	41.2±13.3	0.266
Weight (kg)		64.68 ± 11	59.87 ± 12	0.056
Gender (M/F)		21/30	21/30	1
ASA(I/II)		13/18	15/16	0.609
Type of surgery	Laminectomy& Discectomy	16 (51.62%)	13 (41.94%)	0.122
	Pedicle screw fixation & cord decompression	5 (16.14%)	13 (41.94%)	
	ACDF with cage placement	9 (29%)	4 (12.90%)	
	Detethering of cord	1 (3.24%)	1 (3.24%)	
Duration of surgery(min)		240.2 ± 60.2	213.9 ± 43.8	0.423

Table 2: Distribution of patients according to anaesthesia duration and extubation parameters

	Group N Mean ±SD	**Group S Mean ±SD**	**p value**
Anaesthesia duration (Min)	272.8 ± 62.9	247.2 ± 46.1	0.0386
Time to spontaneous breathing after reversal (Seconds)	607.74 ± 257.16	53.32 ± 29.13	0.0001
Time to respond to verbal commands (Seconds)	724.74 ± 262.03	76.58 ± 31.47	0.0001
Extubation Time (Seconds)	887.70 ± 252.24	102.87 ± 38.17	0.0001

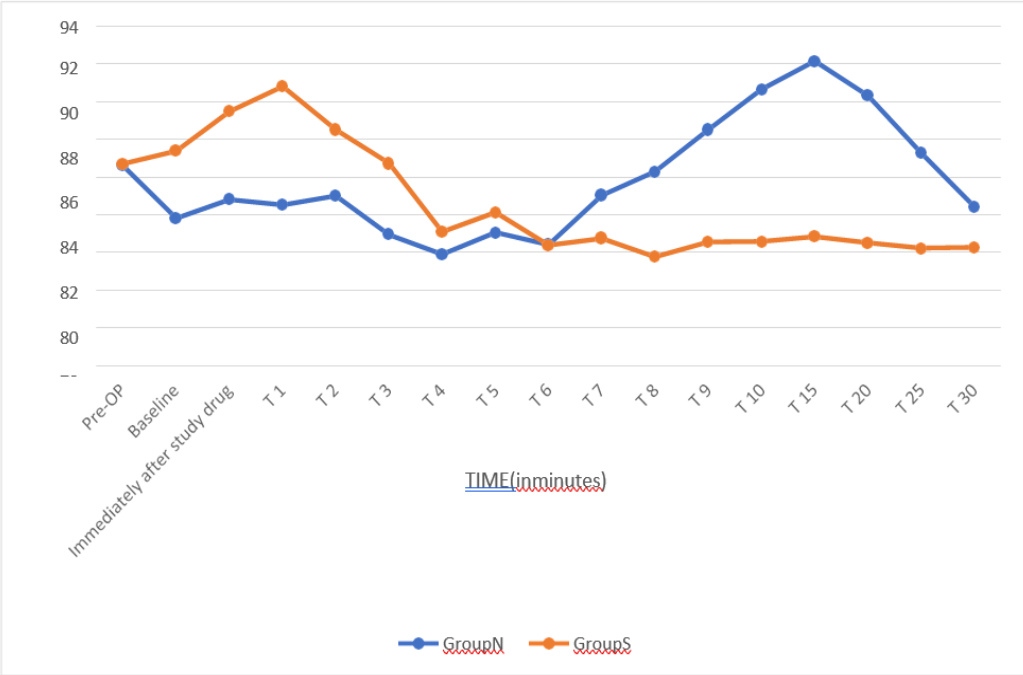

Figure 2: Comparison of heart rate between both the groups

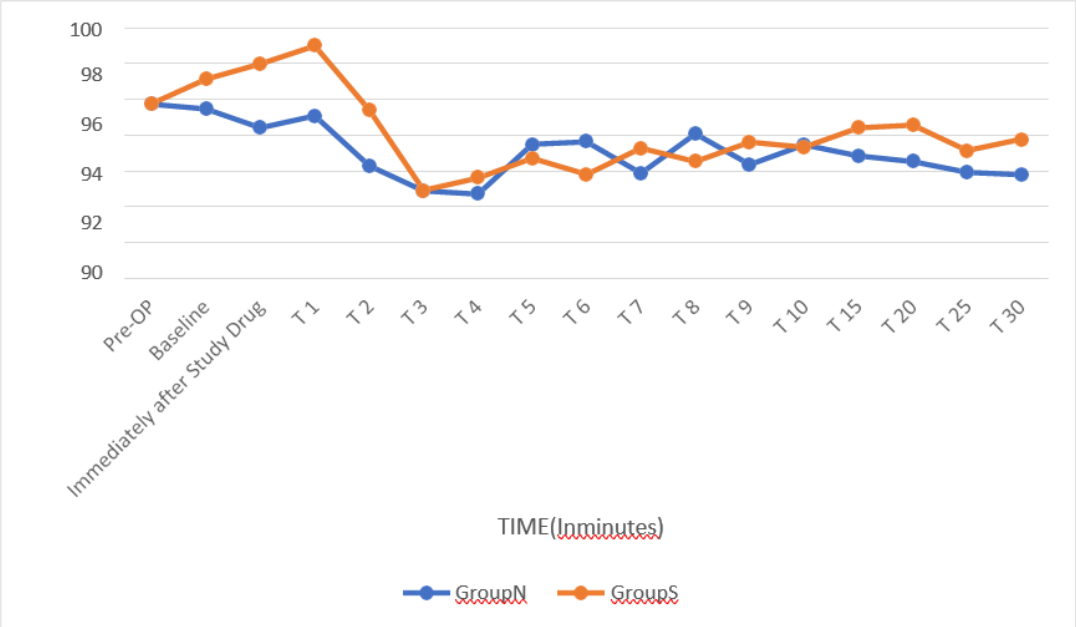

Figure 3: Comparison of mean arterial pressure between both the groups

Table 3: Distribution of patients according to surgeon's satisfaction score.

Score	Group N	Group S	p-value
I (Very Satisfied)	6	15	0.0268
II (Satisfied)	20	15	
III (Not Satisfied)	5	1	

Discussion

We conducted this study to compare the efficacy of sugammadex (a newly introduced NMB reversal agent) with the conventionally used NMB reversal agent neostigmine in antagonizing the effect of rocuronium in patient posted for a variety of spine surgeries. Our study clearly demonstrates the superiority of sugammadex compared to neostigmine in reversing NMB in patients undertaking elective spine surgeries by reducing the time to return of spontaneous respiration, time to follow verbal command, time to extubation as well as total duration of anaesthesia.

The baseline characteristics such as age, gender, weight, and ASA grading were statistically similar across both groups, ensuring a fair comparison. While the duration of surgery was comparable between the groups, the total duration of anaesthesia was substantially shorter in the sugammadex group, indicating a faster and more efficient recovery from anaesthesia. This is attributed to the direct mechanism of action of sugammadex, which encapsulates rocuronium molecules, rendering them inactive. In contrast, neostigmine works indirectly by inhibiting acetylcholinesterase, leading to a slower onset of action due to the gradual accumulation of acetylcholine at the neuromuscular junction.

Our study clearly illustrates the superior performance of sugammadex in key recovery metrics such as time to spontaneous breathing, response to verbal commands and extubation time. Patients in the sugammadex group exhibited significantly faster recovery times across these metrics compared to those in the neostigmine group, highlighting sugammadex's efficiency in facilitating rapid neuromuscular recovery. This rapid reversal ability of sugammadex is especially useful during surgeries which require maintenance of deep NMB throughout the procedure, when surgery ends earlier than expected where rapid reversal of NMB would allow return of spontaneous breathing. Our findings align with those of Mraovic B et al who observed a rapid reversal of rocuronium induced NMB with sugammadex compared to neostigmine in geriatric patients undergoing elective lumbar spine surgery. [15] The variability in reversal times was much lower with sugammadex, suggesting a more predictable and consistent recovery [15]. Similar trends were noted by Blobner M et al who reported longer and more variable reversal times with neostigmine [8]. This consistency across studies reinforces the reliability of sugammadex in providing rapid and predictable neuromuscular blockade reversal. Jones RK et al further corroborate our findings, emphasizing the rapid recovery facilitated by sugammadex. In their study, sugammadex achieved a TOF ratio of 0.9 with a mean of 2.9 min, significantly faster than the 50.4 min required for neostigmine [16]. This rapid reversal is particularly beneficial in spine surgery where maintaining deep neuromuscular blockade is critical, and a swift recovery is essential for efficient surgical turnover and reduced anaesthesia time.

Study done by Tsai YH et al [17] highlighted the haemodynamic stability provided by sugammadex during neurointerventional procedures. They observed more stable HR and MAP values in patients receiving sugammadex as compared to neostigmine. This is particularly relevant in spine surgery, where maintaining stable haemodynamics is crucial to avoid complications during emergence from anaesthesia. The findings from Tsai YH et al align with our observation of stable blood pressure and heart rate patterns in the sugammadex group, suggesting that sugammadex not only facilitates faster recovery but also ensures safer haemodynamic control. In the present study heart rate patterns differed between the groups, with the sugammadex group exhibiting higher heart rates immediately post-reversal and at 1 minute, while the neostigmine group showed elevated heart rates at 8, 9, 10, 15, 20 and 25 minutes post-reversal. The variation in time of occurrence of tachycardia can be attributed to the difference of the two studied drugs reversal time. It’s an established fact that the period of reversal from NMBA is invariably associated with sympathetic stimulation resulting in tachycardia. Despite these differences, SBP, DBP and MAP were statistically comparable between the groups, indicating stable haemodynamics overall.

Sugammadex permanently inactivates NMBA by binding steroidal NMBA molecule within its lipophilic core. This prevents the autonomic instability as seen with administration of anticholinesterase drugs like neostigmine. Due to sugammadex unique effects, use of anticholinergic drugs, which are mandatory coadministered with neostigmine, can be spared. This absence of muscarinic and cardiovascular effects will be of great advantage in cardiac disorder patients.

Although patients who were administered neostigmine took more time for extubation but they were also as awake and calm as the patients who were given sugammadex. Complications were minimal and non-life-threatening in both the groups, which indicates a good safety profile of both the drugs. The implications of our findings for spine surgery are significant. Faster recovery times with sugammadex can lead to reduced anaesthesia time and more efficient operating room turnover.

The haemodynamic stability provided by sugammadex is particularly beneficial in spine surgery, where maintaining stable blood pressure and heart rate is crucial during emergence from anaesthesia. After spine surgeries, surgeon wants to assess motor power immediately postextubation so as to detect any inadvertent injury to spinal nerves. Since patients in sugammadex had early and complete recover of motor power, the surgeons were able to assess the motor power earlier.

Sugammadex is much expensive than neostigmine. Hence, use of sugammadex surely increases the financial burden of the patient or hospital but with widespread use of sugammadex and increasing number of pharmaceutical companies competiting

for their market space, the prices are bound to hit southward.

Our study has some limitations. Firstly, it's a single centre trail and has modest sample size. Moreover, only ASA physical grade I and II patients were enrolled for the study. Furthermore, our study concentrated on patient posted for spine surgeries only. Future studies considering these limitations, are warranted to further substantiate these findings and explore the potential benefits of sugammadex in other surgical contexts.

Our study provides robust evidence supporting the superior efficacy and safety of sugammadex compared to neostigmine in ameliorating NMB in patients undergoing elective spine surgeries. The faster recovery time, stable haemodynamics, equivocal emergence agitation scores and favorable safety profile make sugammadex a preferable choice for NMBA reversal in spine surgeries.

References

1. Oh SK, Kwon WK, Park S, Ji SG, Kim JH, Park YK, et al. Comparison of operating conditions, postoperative pain and recovery and overall satisfaction of surgeons with deep vs no neuromuscular blockade for spinal surgery under general anesthesia: a prospective randomized controlled trial. J Clin Med. 2019; 8(4): 498.
2. Debaene B, Plaud B, Dilly MP, Donati F: Residual paralysis in the PACU after a single intubating dose of nondepolarizing muscle relaxant with an intermediate duration of action. Anesthesiology 2003; 98:1042–8.
3. Murphy GS. Residual neuromuscular blockade: incidence, assessment, and relevance in the postoperative period. Minerva Anestesiol. 2006;72(3):97-109.
4. Shorten GD: Postoperative residual curarisation: Incidence, aetiology and associated morbidity. Anaesth Intensive Care 1993; 21:782–9.
5. Berg H, Roed J, Viby-Mogensen J, Mortensen CR, Engbaek J, Skovgaard LT, etal. Residual neuromuscular block is a risk factor for post-operative pulmonary complications: A prospective, randomised, and blinded study of postoperative pulmonary complications after atracurium, vecuronium and pancuronium. Acta Anaesthesiol Scand 1997; 41(9):1095–103.
6. Bom A, BradleyM, Cameron K, Clark JK, Van Egmond J, Feilden H, etal. A novel concept of reversing neuromuscular block: chemical encapsulation of rocuronium bromide by a cyclodextrin-based synthetic host. Angew Chem 2002; 114:276–80.
7. Naguib M Sugammadex: Another milestone in clinical neuromuscular pharmacology. Anesth Analg. 2007; 104:575–81.
8. Blobner M, Eriksson LI, Scholz J, Motsch J, DellaRocca 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 Anesthesiol 2010; 27(10):874–81.
9. 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(1): 15:1-10.
10. Keating GM. Sugammadex: areview of neuromuscular blockade reversal. Drugs 2016; 76:1041–52.
11. Brull SJ, Naguib M. Elective reversal of muscle relaxation in general anaesthesia: focus on sugammadex. Drug Des Devel Ther 2009; 3:119–29.
12. McDonagh DL, Benedict PE, Kovac AL, Drover DR, Brister NW, Morte JB, etal. Efficacy, safety, and pharmacokinetics of sugammadex for the reversal of rocuronium-induced neuromuscular blockade in elderly patients. Anesthesiology 2011; 114:318-29.
13. Ghoneim AA, Ghoneim AA, El Beltagy MA. Comparative study between sugammadex and neostigmine in neurosurgical anesthesia in pediatric patients. Saudi J Anaesth 2015; 9(3):247-52.
14. Channaiah VB, Kurek NS, Moses R, Chandra SB. Attenuation of haemodynamicresponsetolaryngoscopyandendotrachealintubationwithpre induction IV Fentanyl versus combination of IV Fentanyl and sub lingual nitroglycerin spray. Medical archives 2014; 68:339-44.
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):606-613.
16. 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.
17. Tsai YH, Chen CY, Wong HF, Chou AH. Comparison of neostigmine and sugammadex for hemodynamic parameters in neurointerventional anesthesia. Front Neurol 2023; 14:1-7.