

COMPARISON OF EFFICACY AND SAFETY OF SUGAMMADEX VS NEOSTIGMINE AS A REVERSAL AGENT IN PATIENTS WITH OBSTRUCTIVE SLEEP APNEA UNDERGOING MAJOR ABDOMINAL AND THORACIC SURGERIES – A PROSPECTIVE RANDOMIZED CONTROL STUDY

Praveen Kumar Moturi¹, S Subhalakshmi², Sowjanya Tungana³, Aakash Dhivakaran⁴

Received : 24/08/2026
Received in revised form : 20/09/2026
Accepted : 03/10/2026

Keywords:

Sugammadex, Neostigmine, Obstructive sleep apnoea, Neuromuscular blockade, Pulmonary complications.

Corresponding Author:

Dr. Aakash Dhivakaran
Email: aakashdhiva@gmail.com

DOI: 10.47009/jamp.2026.8.5.115

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2026; 8 (5); 735-739



¹Associate Professor, Department of Anesthesiology, Andhra Medical College, India.

²Senior Resident, JR Medical College and Hospital, Formerly Resident, Andhra Medical College, India.

³Assistant Professor, Andhra Medical College, India.

⁴Junior Resident, Department of Anaesthesiology, Andhra Medical College, India.

ABSTRACT

Background: Patients with obstructive sleep apnoea (OSA) face a heightened risk of postoperative respiratory complications. Residual neuromuscular blockade (rNMB) significantly contributes to airway obstruction and hypoventilation during the perioperative period. While Neostigmine, the traditional reversal agent, shows variable efficacy and is linked to cholinergic side effects, Sugammadex offers a rapid and predictable reversal of steroidal neuromuscular blockade, potentially improving postoperative respiratory outcomes. **Objectives:** This study aims to compare the safety and efficacy of Sugammadex and Neostigmine regarding neuromuscular blockade recovery, postoperative pulmonary complications, adverse events, and recovery profile in OSA patients undergoing significant abdominal and thoracic surgeries. **Materials and Methods:** In a prospective randomized controlled study, approved by the Institutional ethics committee, 120 adult patients with OSA undergoing major abdominal and thoracic surgeries under general anaesthesia were assigned to receive either Sugammadex (n=60) or Neostigmine with an anticholinergic (Glycopyrrolate) (n=60) for the reversal of Vecuronium-induced neuromuscular blockade. Quantitative train-of-four (TOF) monitoring was employed. The primary outcome was the time to achieve a TOF ratio of ≥ 0.9 . Secondary outcomes included postoperative pulmonary complications, adverse events, extubation time, and PACU stay. **Results:** The time to reach TOF ≥ 0.9 was significantly shorter with Sugammadex (2.3 ± 0.9 min) compared to Neostigmine (11.2 ± 4.1 min) ($p < 0.001$). Composite pulmonary complications were observed in 10% of the Sugammadex group versus 28.3% in the Neostigmine group ($p = 0.01$). Adverse events were significantly fewer with Sugammadex (11.7% vs 40%, $p < 0.001$). Both PACU stay and extubation time were notably reduced. **Conclusion:** Sugammadex offers a faster and more reliable reversal of neuromuscular blockade and is linked to fewer respiratory and cholinergic complications compared to Neostigmine in OSA patients. Its preferential use in this high-risk group is clinically advantageous.

INTRODUCTION

Residual neuromuscular blockade is a critical but preventable cause of postoperative respiratory compromise. Even minor levels of residual paralysis can impair upper airway muscle tone, reduce ventilatory response, and increase the risk of hypoxemia and aspiration. These risks are particularly significant in patients with obstructive

sleep apnea (OSA) who naturally exhibit upper airway collapsibility and altered ventilatory control. OSA is increasingly prevalent in surgical populations and is independently correlated with higher postoperative pulmonary complication rates. Therefore, ensuring a safe and complete reversal of neuromuscular blockade is paramount in managing anesthesia for this group.

Neostigmine, an acetylcholinesterase inhibitor, has been widely used to reverse non-depolarizing neuromuscular blockers pharmacologically. However, its effectiveness depends on the depth of the blockade at the time of administration, and incomplete reversal is often documented. Additionally, Neostigmine can cause cholinergic side effects, including bradycardia, bronchospasm, and increased secretions.

Sugammadex, a selective relaxant binding agent, reverses steroidal neuromuscular blocking agents through encapsulation rather than enzymatic inhibition. This mechanism allows for rapid and predictable reversal independent of acetylcholinesterase activity, avoiding cholinergic side effects. This study was conducted to compare Sugammadex and Neostigmine in OSA patients undergoing major abdominal and thoracic surgeries.

MATERIALS AND METHODS

Study Design and Ethics

This prospective, randomized, controlled study was conducted in a tertiary teaching hospital after obtaining institutional ethics committee approval with Serial No: 212/IEC AMC/ August 2024 and obtaining written informed consent. Study was done for a period of fourteen months.

Participants

A total of 120 adult patients aged 19–65 years with diagnosed OSA, ASA physical status I–II, scheduled for major abdominal and thoracic surgeries under general anaesthesia, were enrolled.

Randomization: Patients were randomized into two groups:

- Group S: Sugammadex (n = 60)
- Group N: Neostigmine + Glycopyrrolate (n = 60)

Table 1: Consort Flow of Participants — Study Enrollment and Allocation

Study Stage	Sugammadex Group (Group S)	Neostigmine Group (Group N)	Total (n)
Patients assessed for eligibility	----	----	156
Excluded	-----	-----	36
Not meeting inclusion criteria	-----	-----	22
Declined to participate	-----	-----	9
Other reasons	----	----	5
Randomized	----	----	120
Allocated to intervention	60	60	120
Received allocated intervention	60	60	120
Did not receive allocated intervention	0	0	0
Lost to follow-up	0	0	0
Discontinued intervention	0	0	0
Crossovers	0	0	0
Included in final analysis	60	60	120

A total of 156 patients were screened for eligibility, with 120 meeting the inclusion criteria and being randomized. Sixty patients were allocated to each reversal agent, all of whom completed the study without loss to follow-up.

Anaesthetic Protocol

Anaesthesia was induced with Propofol and maintained with Sevoflurane. Vecuronium was used for neuromuscular blockade, with quantitative TOF monitoring applied.

Reversal Protocol

Upon reappearance of TOF responses, reversal agents were administered according to group allocation. Extubation followed once the TOF ratio was ≥ 0.9 , and clinical recovery was satisfactory.

Outcomes

Primary Outcome

Time from reversal administration to TOF ratio ≥ 0.9

Secondary Outcomes

Extubation time

PACU stay

Postoperative pulmonary complications

Adverse events

Modelled cost analysis

Statistical Analysis

Continuous variables were analysed using the Student's t-test, while categorical variables were compared using the chi-square test. A p-value < 0.05 was considered statistically significant.

RESULTS

Baseline Characteristics

Demographic and perioperative characteristics, including ASA status, OSA severity, duration of anaesthesia, and Vecuronium consumption, were comparable between the groups ($p > 0.05$).

Table 2: Baseline demographic and perioperative characteristics

Variable	Sugammadex (Group S)	Neostigmine (Group N)	P value
Age (years), mean $\pm$ SD	48.6 $\pm$ 9.8	49.9 $\pm$ 10.4	0.52
Male sex, n (%)	41 (68.3)	39 (65.0)	0.70
BMI (kg/m ²), mean $\pm$ SD	31.2 $\pm$ 3.9	30.8 $\pm$ 4.2	0.58

ASA I/II	26 / 34	24 / 36	0.71
Moderate-severe OSA, n (%)	37 (61.7)	35 (58.3)	0.71
Duration of surgery (min)	132 ± 36	136 ± 33	0.49
Duration of anaesthesia (min)	148 ± 32	151 ± 29	0.64
Total Vecuronium dose (mg)	9.8 ± 2.1	10.1 ± 2.4	0.58

Data expressed as mean ± SD. No statistically significant baseline differences were observed.

Neuromuscular Recovery

The time to achieve TOF ≥ 0.9 was significantly shorter with Sugammadex (2.3 ± 0.9 min) compared to Neostigmine (11.2 ± 4.1 min) ($p < 0.001$). Recovery within 3 minutes occurred in 90% of the Sugammadex group versus 10% of the Neostigmine group ($p < 0.001$).

Extubation and PACU Recovery

Recovery after neuromuscular blockade reversal was significantly faster with Sugammadex. The mean time to extubation was 6.1 ± 2.4 minutes for

Sugammadex versus 14.8 ± 5.3 minutes for Neostigmine ($p < 0.001$).

Early postoperative recovery parameters also favoured sugammadex. The PACU stay was shorter for Sugammadex (52 ± 18 minutes) compared to Neostigmine (68 ± 22 minutes) ($p = 0.004$). A greater proportion of patients in the neostigmine group required extended PACU observation due to delayed recovery of airway tone, residual weakness, or transient oxygen desaturation.

These findings indicate that faster pharmacological reversal with sugammadex translated into earlier Extubation readiness and more efficient immediate postoperative recovery.

Table 3: Neuromuscular recovery and early postoperative outcomes

Outcome	Sugammadex (Group S)	Neostigmine (Group N)	P value
Time to TOF ≥ 0.9 (min)	2.3 ± 0.9	11.2 ± 4.1	<0.001
Recovery within 3 min, n (%)	54 (90.0)	6 (10.0)	<0.001
Time to extubation (min)	6.1 ± 2.4	14.8 ± 5.3	<0.001
PACU stay (min)	52 ± 18	68 ± 22	0.004
Clinical residual weakness in PACU, n (%)	3 (5.0)	16 (26.7)	0.002

*TOF = train-of-four; PACU = post-anaesthesia care unit

Postoperative Pulmonary Complications

The incidence of postoperative pulmonary complications was significantly lower with Sugammadex. Composite pulmonary complications were observed in 10% of the Sugammadex group versus 28.3% in the Neostigmine group ($p = 0.01$), corresponding to a relative risk reduction of approximately 65%.

Episodes of postoperative oxygen desaturation ($\text{SpO}_2 < 90\%$) were observed in 8.3% of patients in the Sugammadex group versus 23.3% in the neostigmine group ($p = 0.02$). These desaturation events were frequently associated with partial airway obstruction and residual neuromuscular weakness and typically required airway repositioning and supplemental oxygen.

The requirement for non-invasive ventilatory support was also significantly lower in the sugammadex group (3.3% vs 15%, $p = 0.03$). Patients requiring non-invasive ventilation predominantly belonged to the neostigmine group and had evidence of persistent hypoventilation or upper airway collapse in the early recovery period.

Radiologically confirmed atelectasis and clinically suspected lower respiratory infection were less frequent in the sugammadex group, although

individual event rates were low. Overall, pulmonary morbidity showed a consistent reduction with sugammadex reversal.

Adverse Events

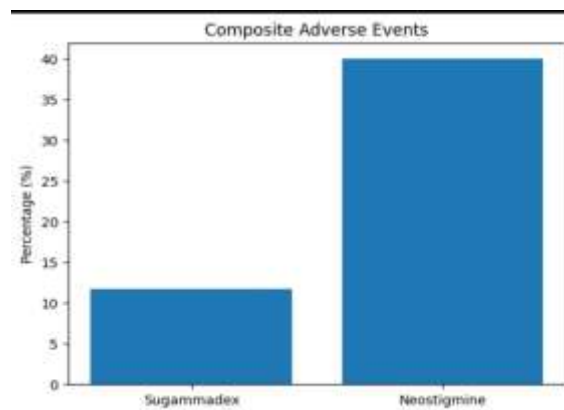
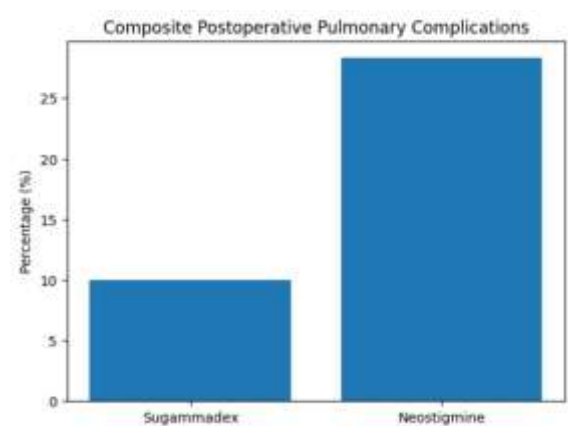
Sugammadex had significantly fewer adverse events than Neostigmine, particularly cholinergic effects. Bradycardia requiring intervention occurred in 1.7% of the Sugammadex group compared to 18.3% of the Neostigmine group ($p = 0.003$). These episodes typically occurred within minutes of neostigmine administration and were responsive to anticholinergic therapy.

Bronchospasm occurred in 1.7% of patients reversed with sugammadex compared with 11.7% in the neostigmine group ($p = 0.03$). Bronchospastic episodes were transient but required bronchodilator therapy and closer respiratory monitoring.

Increased airway secretions and the need for repeated suctioning were also more frequently observed after neostigmine administration, although these events were not always formally classified as complications. Collectively, the adverse event profile favoured sugammadex, reflecting its mechanism of action independent of acetylcholinesterase inhibition and avoidance of systemic cholinergic effects.

Table 4: Postoperative pulmonary complications and adverse events

Outcome	Sugammadex (Group S)	Neostigmine (Group N)	Relative Risk	P value
Composite Pulmonary Complications	6 (10.0%)	17(28.3%)	0.35	0.01
Desaturation <90%	5 (8.3%)	14 (23.3%)	0.36	0.02
Atelectasis	2 (3.3%)	8 (13.3%)	0.25	0.048
Pneumonia	1 (1.7%)	5 (8.3%)	0.20	0.09
Need for NIV	2 (3.3%)	9 (15%)	0.22	0.03
Reintubation	0	3 (5.0%)	----	0.08
Composite Adverse Events	7 (11.7%)	24 (40.0%)	0.29	<0.001
Bradycardia	1 (1.7%)	11 (18.3%)	0.09	0.003
Bronchospasm	1 (1.7%)	7 (11.7%)	0.14	0.03



Cost Analysis

A comparative cost analysis was performed using a predefined perioperative cost model incorporating reversal drug procure cost and complication-related resources utilization. Direct drug costs were calculated based on institutional procurement prices and standard weight-based dosing. Indirect perioperative costs included extended PACU stay, need for non-invasive ventilatory support, ICU admission, additional respiratory therapy, and diagnostic investigations related to postoperative pulmonary complications.

Table 5: Perioperative Cost Analysis (Modeled) — Sugammadex vs Neostigmine

Cost Component	Sugammadex (n = 60) Mean ± SD (₹)	Neostigmine (n = 60) Mean ± SD (₹)	p Value
Reversal drug acquisition cost	715 ±225	140 ± 43	<0.001
PACU resource utilization cost	4,200 ± 1,100	5,600 ± 1,400	0.002
Respiratory intervention cost	1,100 ± 900	2,800 ± 1,900	0.01
Complication-related treatment cost	2,600 ± 1,800	4,700 ± 3,200	0.006
Extended monitoring / investigations	1,800 ± 900	2,500 ± 1,200	0.01
Total modeled perioperative cost per patient	19,600 ± 1,200	17900 ± 1900	0.31

As expected, the mean acquisition cost of the reversal agent was significantly higher in the sugammadex group compared with the neostigmine group. The average per-patient reversal drug cost in the sugammadex arm was approximately three to four times greater than that of neostigmine with anticholinergic co-administration.

However, patients in the neostigmine group demonstrated a higher incidence of postoperative pulmonary complications and adverse events, which translated into increased downstream resource utilization. These included longer PACU stays,

greater requirement for supplemental oxygen and non-invasive ventilation, more frequent respiratory interventions, and higher rates of unplanned escalation of care. PACU occupancy time was significantly prolonged in the neostigmine group, contributing to increased recovery room resource consumption.

When complication-related and recovery-related costs were incorporated into the model, the difference in total perioperative cost between groups narrowed substantially and the difference was not statistically significant (p = 0.31).

DISCUSSION

This study demonstrates that Sugammadex provides a faster and more reliable reversal of Vecuronium-induced neuromuscular blockade than Neostigmine in patients with obstructive sleep apnea undergoing major abdominal and thoracic surgeries. The faster recovery led to earlier extubation readiness and a shorter PACU stay, representing a significant improvement in immediate postoperative recovery. Sugammadex's efficacy in neuromuscular recovery aligns with prior studies and meta-analyses showing that encapsulation-based reversal is rapid and predictable. In contrast, Neostigmine's reversal depends on blockade depth and synaptic acetylcholine availability, which can result in incomplete or delayed recovery.

A key finding is the significant reduction in postoperative pulmonary complications with Sugammadex, particularly relevant for OSA patients who are susceptible to upper airway collapse and hypoventilation. Sugammadex also had a lower incidence of adverse events, especially bradycardia and bronchospasm, due to its mechanism of action independent of acetylcholinesterase activity. From a resource utilization perspective, while Sugammadex has a higher acquisition cost, the observed reductions in PACU stay and complications may offset the higher initial expenditure, especially in high-risk populations like OSA patients.

Limitations of the Study

The study was conducted at a single centre, and although adequately powered for recovery and complication endpoints, it was not powered for rare outcomes such as pneumonia or reintubation individually. Cost analysis was model-based and dependent on institutional pricing and resource assumptions, which may limit generalizability. In addition, only Vecuronium-induced blockade was evaluated.

Future multicentre studies with larger sample sizes and formal cost-effectiveness modelling would further clarify the economic and clinical impact of sugammadex use in high-risk respiratory populations.

CONCLUSION

In OSA patients undergoing major surgery, Sugammadex provides faster, more predictable, and more complete reversal of neuromuscular blockade than Neostigmine. Its use is associated with earlier extubation, shorter PACU stays, fewer postoperative pulmonary complications, and significantly fewer cholinergic adverse events. Despite a higher acquisition cost, the overall clinical and recovery

advantages support the preferential use of Sugammadex where available.

Conflicts of Interest

There are no conflicts of interest related to this study.

Financial Support and Sponsorship

This study received no external financial support and was conducted as part of an academic research project within the department.

Disclosure of use of AI Tools:

No AI – Assistive or generative tools were used for writing manuscript except for grammatical correction.

Acknowledgements: The authors acknowledge the support of the Department of Anaesthesiology, Andhra Medical College, and the PACU and operating room staff for their assistance in patient monitoring and data collection.

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