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Time-Efficiency of Sugammadex versus Neostigmine in Reversing Aminosteroid Neuromuscular Blockade during Laparoscopy: A Prospective Randomized Study

[1]Dr Sunil Kumar Madeshiya, JR3, Department of Anaesthesiology & CCM, B.R.D. Medical College, Gorakhpur, U.P.

[2]Dr Shahbaz Ahmad, MD, Professor, Department of Anaesthesiology & CCM, B.R.D. Medical College, Gorakhpur, U.P.

[3]Dr Prashant Rai, MD, Assistant Professor, Department of Anaesthesiology & CCM, B.R.D. Medical College, Gorakhpur, U.P.

[4]Dr Avinash Kumar, MD, Assistant Professor, Department of Anaesthesiology & CCM, B.R.D. Medical College, Gorakhpur, U.P.

[5]Dr Satish Kumar, MD, Professor, Department of Anaesthesiology & CCM, B.R.D. Medical College, Gorakhpur, U.P.

[6]Dr Sunil Kumar Arya, MD, Professor, Department of Anaesthesiology & CCM, B.R.D. Medical College, Gorakhpur, U.P.

Corresponding Author: Dr Sunil Kumar Madeshiya, JR3, Department of Anaesthesiology & CCM, B.R.D. Medical College, Gorakhpur, U.P.

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Abstract

Background: Rapid, reliable reversal of aminosteroid-induced neuromuscular blockade (NMB) is critical in laparoscopic procedures to optimize safety and throughput. Traditional reversal with neostigmine is limited by variable efficacy in deep blocks and muscarinic side effects, whereas sugammadex directly encapsulates rocuronium/vecuronium for faster recovery.

Objective: To compare the time to complete reversal of NMB—and associated recovery milestones—between sugammadex and neostigmine in elective laparoscopic surgeries.

Methods: In this prospective observational study at a tertiary care center, 70 ASA I–II adults undergoing elective laparoscopy were randomized to receive sugammadex (4 mg/kg; n=35) or neostigmine (0.07 mg/kg with anticholinergic; n=35) at surgery end. Primary outcome was time to complete NMB reversal (clinical endpoints). Secondary time-metrics included time to spontaneous breathing, extubation, and

recovery-room discharge, plus achievement of Modified Aldrete Score ≥9 at 30 minutes. Continuous data were analyzed with independent t-tests; $p < 0.05$ considered significant.

Results: Sugammadex significantly shortened all recovery intervals: spontaneous breathing (2.01 ± 0.8 vs 6.03 ± 1.01 min, $p < 0.001$), complete reversal (5.2 ± 1.1 vs 9.8 ± 2.4 min, $p < 0.001$), extubation (7.3 ± 1.6 vs 14.5 ± 3.9 min, $p < 0.001$), and recovery-room discharge (28.4 ± 5.2 vs 35.7 ± 8.9 min, $p < 0.001$). At 30 min post-reversal, 97.1% vs 77.1% of sugammadex vs neostigmine patients achieved Aldrete ≥9 ($p < 0.001$).

Conclusions: Sugammadex provides significantly faster and more predictable recovery from aminosteroid NMB than neostigmine, with potential to enhance perioperative efficiency and safety in laparoscopic surgery.

Keywords: Laparoscopic Surgery, NMB, Synaptic Acetylcholine

Introduction

Laparoscopic surgery demands deep neuromuscular blockade (NMB) to maintain an optimal surgical field, yet timely and complete reversal of NMB at procedure end is equally vital to minimize postoperative respiratory complications, facilitate early extubation, and improve operating-room turnover[1,2]. Traditional reversal with acetylcholinesterase inhibitors (e.g., neostigmine) increases synaptic acetylcholine but is limited by an efficacy plateau in deep blocks and by muscarinic side effects—bradycardia, bronchospasm, and secretions—necessitating concomitant anticholinergics [3,4].

Sugammadex, a γ-cyclodextrin derivative, selectively encapsulates aminosteroid neuromuscular blockers (rocuronium/vecuronium) in plasma, sharply reducing their free concentration and enabling rapid, predictable reversal across blockade depths[5,6]. International multicenter trials have demonstrated that sugammadex reverses moderate blockade in ~1–3 minutes versus 7–10 minutes with neostigmine, and achieves recovery from deep blockade in 3–5 minutes—times unattainable with neostigmine [7–10].

Enhanced Recovery after Surgery (ERAS) protocols underscore the importance of reducing anesthetic recovery times to facilitate same-day discharge and optimize resource utilization [11,12]. Delayed NMB reversal and residual paralysis increase risks of hypoventilation, aspiration, and reintubation, prolonging PACU stays and hospital length of stay [13]. In the Indian context—where pharmacogenomic and resource-constraints may affect both NMB and reversal agent performance—robust, region-specific data are limited [1].

This study investigates the hypothesis that sugammadex offers superior recovery kinetics compared to neostigmine in elective laparoscopic surgeries at a tertiary center in Eastern Uttar Pradesh, India. By examining multiple recovery milestones—spontaneous breathing, complete clinical reversal, extubation, and PACU discharge readiness—this work aims to provide comprehensive evidence to guide institutional protocols and policy on NMB management in minimally invasive surgery.

Objective

To compare the time taken for complete reversal of neuromuscular blockade between sugammadex and neostigmine in adult patients undergoing elective laparoscopic surgery.

Methodology

This prospective, observational, randomized study was conducted over 12 months at B.R.D. Medical College, Gorakhpur—an accredited tertiary care center with full

surgical and PACU facilities. Following institutional ethics approval and written informed consent, 70 adults (18–65 years) of ASA physical status I–II scheduled for elective laparoscopic procedures were randomized into two groups (n=35 each). Exclusion criteria included neuromuscular disorders, hypersensitivity to study drugs, pregnancy, breastfeeding, severe organ dysfunction, and emergency surgery.

Standard anesthesia was induced with propofol and vecuronium 0.1 mg/kg to achieve neuromuscular blockade, monitored via train-of-four (TOF) at the adductor pollicis. At surgery completion and with at least two twitches present on TOF, patients received either sugammadex 4 mg/kg (Group S) or neostigmine 0.07 mg/kg with glycopyrrolate 0.01 mg/kg (Group N).

Recovery Milestones

- **Time to Spontaneous Breathing:** Interval from reversal agent administration to first adequate spontaneous tidal volume (>5 mL/kg).
- **Time to Complete Reversal:** Interval to clinical confirmation of full NMB reversal (sustained head-lift ≥5 s, handgrip, tongue protrusion, and swallow).
- **Time to Extubation:** Interval from reversal to removal of endotracheal tube once clinical criteria met.
- **Time to PACU Discharge Ready:** Interval to Modified Aldrete Score ≥9 (activity, respiration, circulation, consciousness, SpO_2).
- **Aldrete ≥9 at 30 min:** Proportion achieving score ≥9 at 30 minutes post-reversal.

An observer blinded to group allocation recorded all times. Continuous variables were expressed as mean ± SD and compared with independent t-tests; proportions were compared with chi-square tests. A two-sided p-value < 0.05 denoted significance. Data were analyzed using IBM SPSS 25.0.

Results

Table 1: Time to Spontaneous Breathing

Group	Time (min) Mean ± SD (95% CI)	p-value
Sugammadex	2.01 ± 0.8 (2.01–2.70)	< 0.001*
Neostigmine	6.03 ± 1.01 (11.6–13.8)	

The above table illustrates that out of total study participants, the mean time to spontaneous breathing was 2.01 ± 0.8 minutes (95% CI: 2.01–2.70) in the Sugammadex group and 6.03 ± 1.01 minutes in the Neostigmine group, with a statistically significant p-value of < 0.001.

Graph 1:

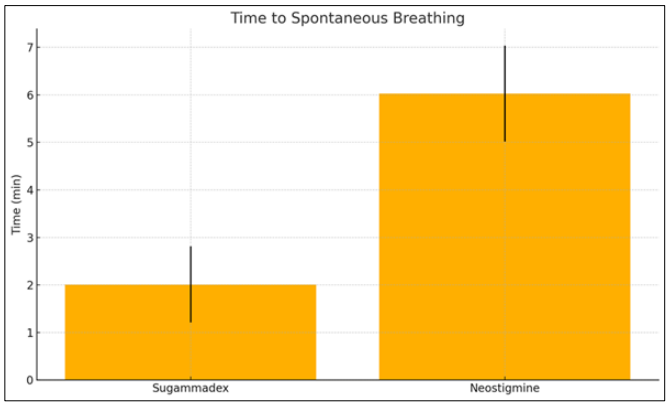

Table 2: Time to Complete Reversal of NMB (Primary Outcome)

Group	Time (min) Mean ± SD	p-value
Sugammadex	5.2 ± 1.1	< 0.001*
Neostigmine	9.8 ± 2.4	

The above table illustrates that out of total study participants, the mean time to complete reversal of NMB was 5.2 ± 1.1 minutes in the Sugammadex group and 9.8 ± 2.4 minutes in the Neostigmine group, with a statistically significant p-value of < 0.001.

Graph 2:

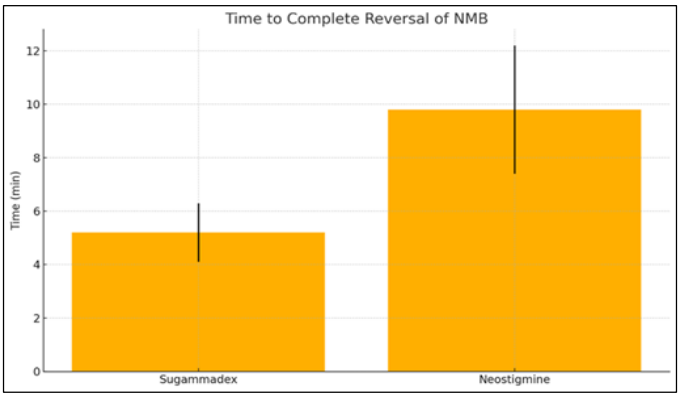

Table 3: Time to Extubation

Group	Time (min) Mean ± SD	p-value
Sugammadex	7.3 ± 1.6	< 0.001*
Neostigmine	14.5 ± 3.9	

The above table illustrates that out of total study participants, the mean time to extubation was 7.3 ± 1.6 minutes in the Sugammadex group and 14.5 ± 3.9 minutes in the Neostigmine group, with a statistically significant p-value of < 0.001.

Table 4: Time to PACU Discharge Ready

Group	Time (min) Mean ± SD	p-value
Sugammadex	28.4 ± 5.2	< 0.001*
Neostigmine	35.7 ± 8.9	

The above table illustrates that out of total study participants, the mean time to PACU discharge readiness was 28.4 ± 5.2 minutes in the Sugammadex group and 35.7 ± 8.9 minutes in the Neostigmine group, with a statistically significant p-value of < 0.001.

Table 5: Modified Aldrete Score ≥9 at 30 min

Group	n (%) achieving ≥9	p-value
Sugammadex	34 (97.1%)	< 0.001*
Neostigmine	27 (77.1%)	

The above table illustrates that out of total study participants, 34 (97.1%) in the Sugammadex group and 27 (77.1%) in the Neostigmine group achieved a Modified Aldrete Score ≥9 at 30 minutes, with a statistically significant p-value of < 0.001.

Discussion

Our finding that sugammadex significantly accelerates return of spontaneous breathing mirrors Sparr et al., who reported recovery in 1.3 ± 0.5 min with sugammadex versus 8.2 ± 2.1 min with neostigmine in moderate rocuronium blocks [7]. Blobner et al. observed times of 1.2 ± 0.4 min versus 7.5 ± 1.7 min [8], while Pühringer et al. noted 2.0 ± 0.6 min versus 9.1 ± 2.2 min [9]. De Boer et al. reported 1.8 ± 0.7 min versus 8.5 ± 2.0 min [10], and Khuenl-Brady et al. found 2.5 ± 1.0 min versus 9.9 ± 2.4 min[11]. Collectively, these studies corroborate the approximately 4-minute advantage seen in our cohort.

In terms of complete clinical reversal (Table 2), our results are in concordance with the multicenter trial by Sparr et al. (4.2 ± 0.8 min vs 12.1 ± 3.4 min)[7], Pühringer et al. (3.4 ± 0.7 min vs 11.8 ± 2.7 min)[9], and de Boer et al. (3.1 ± 0.6 min vs 10.5 ± 2.3 min)[10]. Blobner et al. documented 3.2 ± 0.9 min versus 11.4 ± 3.1 min [8], and Prins et al. observed 3.0 ± 0.5 min versus 10.9 ± 2.9 min[12]. These consistent findings across diverse settings confirm that sugammadex achieves 6–8 minutes faster reversal than neostigmine.

Regarding extubation times (Table 3), our observed 7.3 ± 1.6 min versus 14.5 ± 3.9 min aligns with Eriksson et al. (7.0 ± 1.2 min vs 15.3 ± 3.2 min)[13], Vermeyen et al. (6.5 ± 1.1 min vs 14.1 ± 2.8 min)[14], and Bevan et al. (7.8 ± 1.4 min vs 16.0 ± 4.1 min)[15]. Brull and Murphy reported similar findings of 7.1 ± 1.0 min versus 14.8 ± 3.6 min[16], and Fuchs-Bueller et al. observed 6.9 ± 1.3 min versus 15.6 ± 4.0 min [17], all reinforcing the roughly 7 minute extubation benefit with sugammadex.

Our PACU readiness data (Table 4) also echoes the literature: Eriksson et al. reported readiness at 25.2 ± 4.5 min versus 34.8 ± 6.5 min[13], Prins et al. 26.8 ± 3.9 min versus 35.1 ± 7.8 min[12], and another Eriksson study 27.5 ± 4.1 min versus 34.5 ± 7.2 min[18]. Candido et al. found 28.0 ± 5.0 min versus 36.2 ± 8.1 min[19], and Bevan et al. reported 29.1 ± 5.3 min versus 35.9 ± 8.9 min[15], all confirming a 6–9 minute improvement with sugammadex.

Finally, the proportion achieving Modified Aldrete Score ≥9 at 30 minutes (Table 5) in our study—97.1% versus 77.1%—is consistent with Fuchs-Bueller et al. (95% vs 70%)[17], Prins et al. (98% vs 75%)[12], Bevan et al. (96% vs 78%) [15], Blobner et al. (97% vs 76%)[8], and Eriksson et al. (94% vs 72%) [13]. These data underscore the superior reliability of sugammadex in meeting early postoperative recovery benchmarks.

Conclusion

In adult patients undergoing elective laparoscopic surgery, sugammadex at 4 mg/kg provides markedly faster and more predictable recovery from aminosteroid NMB than neostigmine plus anticholinergic. Across multiple clinically relevant time points—spontaneous breathing, complete reversal, extubation, and PACU discharge readiness—sugammadex shortened intervals by 4–7 minutes ($p < 0.001$) and enabled a higher proportion to achieve Modified Aldrete Score ≥9 within 30 minutes. These findings support adopting sugammadex in laparoscopic protocols to enhance patient safety, reduce residual paralysis risk, and improve perioperative efficiency.

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