

## Efficacy and Safety of Sugammadex in Reversal of Neuromuscular Blockade Induced by Rocuronium versus Vecuronium: A Comparative Prospective Study

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### Abstract:

**Background:** Residual neuromuscular blockade remains an important concern in anaesthetic practice because it may delay recovery and increase postoperative respiratory complications. Sugammadex provides selective reversal of aminosteroidal neuromuscular blockers such as rocuronium and vecuronium.

**Objectives:** To compare the efficacy and safety of sugammadex in reversing neuromuscular blockade induced by rocuronium versus vecuronium.

**Methods:** This prospective randomized comparative study included 30 adult patients undergoing elective surgery under general anaesthesia. Patients were allocated into two groups of 15 each: Group R received rocuronium and Group V received vecuronium. Neuromuscular recovery was monitored using train-of-four stimulation. Sugammadex was administered at the end of surgery according to the depth of blockade. The primary outcome was time to recovery to a train-of-four ratio  $\geq 0.9$ . Secondary outcomes included duration of blockade, time to extubation, and adverse events.

**Results:** Recovery time was significantly shorter in Group R than in Group V ( $2.1 \pm 0.7$  vs  $3.4 \pm 1.1$  min;  $p < 0.001$ ). Duration of blockade and extubation time were also significantly shorter in Group R ( $p = 0.01$  and  $p = 0.002$ , respectively). Adverse events were minimal and similar in both groups.

**Conclusion:** Sugammadex effectively reversed both agents, more favorable with rocuronium than with vecuronium.

**Keywords:** Sugammadex, Rocuronium, Vecuronium, Neuromuscular blockade, Train-of-four monitoring.

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### Introduction

Neuromuscular blocking agents are essential during general anaesthesia to facilitate tracheal intubation and provide adequate muscle relaxation for surgery, but incomplete recovery from blockade remains an important perioperative safety concern because it can contribute to airway compromise, hypoventilation, postoperative pulmonary complications, and delayed recovery [1, 2]. Rocuronium and vecuronium are widely used aminosteroidal neuromuscular blockers because of their favorable pharmacodynamic characteristics, yet both require reliable reversal to avoid residual neuromuscular weakness [1, 3]. Although neostigmine has long been used for reversal, its onset may be slower and less predictable, particularly in deeper levels of blockade, and its indirect mechanism does not always ensure complete recovery [3]. Sugammadex, a modified

gamma-cyclodextrin, reverses rocuronium- and vecuronium-induced neuromuscular blockade by directly encapsulating free drug molecules, producing faster and more dependable recovery than conventional reversal in many settings [3-5]. However, optimal clinical use still depends on appropriate dosing, monitoring, and safety evaluation [1, 2]. Therefore, this prospective comparative study aimed to evaluate the efficacy and safety of sugammadex in reversing rocuronium- versus vecuronium-induced neuromuscular blockade.

### Methods

This was a prospective randomized comparative study conducted in Gayatri Vidya Parishad Institute of Health Care and Medical Technology between January and April 2025. Individuals between 18–65

years with American Society of Anaesthesiologists (ASA) physical status I or II, scheduled for elective surgery under general anaesthesia requiring neuromuscular blockade, were included. Patients with renal impairment, significant hepatic dysfunction, neuromuscular disorders, pregnancy, drug hypersensitivity, or unreliable neuromuscular monitoring were excluded. Institutional Ethics Committee approval and written informed consent were obtained before study commencement. The study members were randomized by simple randomization into Group R (rocuronium) and Group V (vecuronium).

All study members underwent detailed pre-anaesthetic assessment and followed standard fasting guidelines. In the operating room, routine monitoring was established, including electrocardiography, non-invasive blood pressure, pulse oximetry, capnography, and train-of-four (TOF) monitoring at the adductor pollicis muscle. General anaesthesia was induced with intravenous fentanyl and propofol in standard clinical doses. Group R received rocuronium 0.6 mg/kg intravenously, whereas Group V received vecuronium 0.1 mg/kg intravenously to facilitate tracheal intubation. Anaesthesia was maintained with inhalation agents, oxygen, nitrous oxide, and intermittent doses of the assigned neuromuscular blocking drug as required.

At the end of surgery, sugammadex was administered intravenously according to the depth of neuromuscular blockade, using 2 mg/kg for moderate and 4 mg/kg for deep blockade. The primary outcome was the time from sugammadex administration to recovery of neuromuscular function, defined as achievement of a TOF ratio  $\geq 0.9$ . Secondary outcomes included duration of neuromuscular blockade, time to extubation after

reversal, and adverse events such as bradycardia, hypotension, postoperative nausea and vomiting, residual neuromuscular blockade, and hypersensitivity reactions. Data were recorded in a structured proforma and analyzed using SPSS version 21. Continuous variables were compared using the independent samples t-test, categorical variables using chi-square test and recovery profiles using Kaplan-Meier survival analysis with log-rank test.  $P < 0.05$  was considered statistically significant.

## Results

Thirty (100%) members were analyzed in this study, 15 per group. Baseline characteristics were comparable between the groups; there was no statistically significant difference in age, body weight, or ASA status (Table 1). The primary endpoint, time to recovery of neuromuscular function to a TOF ratio  $\geq 0.9$  after sugammadex administration, was significantly shorter in the Group R,  $2.1 \pm 0.7$  min and  $3.4 \pm 1.1$  min respectively ( $P < 0.001$ ) (Table 2). Similarly, the mean duration of neuromuscular blockade was significantly shorter in the Group R,  $38.5 \pm 6.2$  min and  $45.7 \pm 7.1$  min respectively ( $P = 0.01$ ) (Table 2). Time to extubation after reversal was also significantly reduced in Group R,  $3.6 \pm 1.2$  min and  $5.1 \pm 1.5$  min respectively, ( $P = 0.002$ ) (Table 2). Kaplan-Meier analysis further demonstrated a significantly faster cumulative recovery profile in the Group R, and the log-rank test confirmed this difference was significant ( $P < 0.001$ ), reinforcing the consistency of the primary outcome findings across time-to-event analysis (Figure 3). Overall, sugammadex effectively reversed neuromuscular blockade in both groups, but reversal was significantly faster recover and was observed among individuals in Group R (Table 2).

**Table 1: Demographic characteristics among the study members in groups**

| Parameter   | Group R         | Group V        | P value |
|-------------|-----------------|----------------|---------|
| Age (years) | $42.6 \pm 10.4$ | $40.8 \pm 9.7$ | 0.61    |
| Weight (kg) | $68.2 \pm 8.3$  | $66.7 \pm 7.9$ | 0.58    |
| ASA I       | 10              | 9              | 0.74    |
| ASA II      | 5               | 6              |         |

**Table 2: Recovery parameters among the study members in groups**

| Parameter                       | Group R            | Group V            | P value   |
|---------------------------------|--------------------|--------------------|-----------|
| Recovery time (TOF $\geq 0.9$ ) | $2.1 \pm 0.7$ min  | $3.4 \pm 1.1$ min  | $< 0.001$ |
| Duration of blockade            | $38.5 \pm 6.2$ min | $45.7 \pm 7.1$ min | 0.01      |
| Extubation time                 | $3.6 \pm 1.2$ min  | $5.1 \pm 1.5$ min  | 0.002     |

## Discussion

The present study showed that sugammadex produced effective reversal of neuromuscular blockade in both the rocuronium and vecuronium groups, but recovery was significantly faster after rocuronium, as reflected by the shorter time to

achieve a TOF ratio of at least 0.9, the shorter duration of blockade, and the earlier time to extubation [6, 7]. These findings are clinically important because residual neuromuscular blockade continues to be recognized as a major perioperative safety issue despite advances in anaesthetic drugs

and monitoring, and it has been linked with airway obstruction, hypoxemia, impaired upper airway muscle function, delayed recovery, and postoperative pulmonary complications [1, 2]. Recent guidelines from ASA and European Society of Anaesthesiology and Intensive Care have emphasized that reversal of neuromuscular blockade should not be regarded as a routine final step, but rather as a critical component of patient safety that must be integrated with objective neuromuscular monitoring and appropriate choice of antagonist [6, 7]. In that context, the present findings support the growing body of evidence that sugammadex provides rapid, reliable, and clinically meaningful antagonism of aminosteroidal neuromuscular block and that its performance remains particularly favorable when rocuronium is the relaxant used [6–8]. Because both groups were comparable at baseline, the observed difference in recovery profile is likely to reflect pharmacologic differences between the two neuromuscular blocking agents rather than demographic imbalance or confounding from preoperative status [7].

Rapid recovery observed in the rocuronium group is biologically plausible and is consistent with current understanding of sugammadex–drug interactions [8, 9]. Sugammadex reverses neuromuscular blockade by encapsulating free aminosteroidal relaxant molecules in plasma, thereby decreasing the amount of active drug available at the neuromuscular junction and creating a concentration gradient that favors movement of the blocker away from the receptor [8, 9]. Contemporary mechanistic work has shown that the interaction between sugammadex and rocuronium is more avid and structurally favorable compared with vecuronium, with rocuronium forming more stable interactions and more hydrogen bonds during encapsulation, a finding that offers a molecular explanation for the faster clinical reversal often seen with rocuronium [8]. Recent narrative reviews have also reaffirmed that although sugammadex is highly effective for both rocuronium and vecuronium, reversal tends to be quicker and more predictable with rocuronium, especially when quantitative monitoring is used and when recommended dosage is followed [1, 9]. The mean recovery time in the present study was  $2.1 \pm 0.7$  minutes and  $3.4 \pm 1.1$  minutes, respectively, which fits well within the rapid-reversal range reported in modern literature and suggests that the difference observed is not merely statistically significant but also clinically relevant [1, 8, 9]. This pattern is important in real-world anaesthesia because a modest reduction in reversal time may simplify emergence, reduce uncertainty at extubation, and improve operating room workflow in busy elective theatre settings [5, 10].

The second major observation in the present study was the significantly earlier extubation in the Group

R; this reflects the faster restoration of diaphragmatic function, upper airway muscle tone, and protective airway reflexes after antagonism of blockade [1, 2, 5]. Earlier extubation is not simply a time-based endpoint; it is a clinically meaningful marker of recovery because it is closely connected with readiness for safe emergence, return of spontaneous ventilation, and transition to postoperative care [1, 2]. Recent evidence suggests that sugammadex-based reversal may positively influence downstream recovery variables, including postoperative respiratory stability and efficiency of discharge pathways, particularly in ambulatory and fast-track practice [5, 11]. A multicentre study reported that the pharmacodynamic advantages of sugammadex can translate into measurable improvements in postoperative throughput after ambulatory surgery, while others suggested that more complete reversal may reduce respiratory events linked to residual block [5, 11]. A 2023 systematic review and meta-analysis further concluded that sugammadex was associated with lower rates of several postoperative pulmonary complications compared with neostigmine, although the authors also noted the need for further randomized data to refine the magnitude of benefit across settings [11]. In this study, we did not compare sugammadex with neostigmine and did not include longer postoperative respiratory endpoints, but the shorter extubation time and absence of residual paralysis in the rocuronium group are directionally consistent with the broader literature supporting the clinical value of rapid and complete reversal [5, 11]. Therefore, the present findings are relevant not only at the pharmacologic level but also within enhanced recovery strategies, where minutes saved at emergence may contribute to smoother perioperative flow and potentially better short-term respiratory outcomes [10, 11].

The safety profile observed in the present study was favorable, with some individuals experiencing mild bradycardia, transient hypotension, and postoperative nausea, and with no clinically evident recurarization, severe hypersensitivity, or postoperative residual neuromuscular blockade [1, 12]. This is in line with recent reviews describing sugammadex as generally well tolerated when used in correct doses and with adequate monitoring, while still recognizing that vigilance is necessary because no reversal strategy is completely risk-free [1,10]. Importantly, the present study used objective TOF monitoring and defined recovery as a ratio of at least 0.9, which strengthens the validity of the findings because quantitative neuromuscular monitoring is now regarded as central to safe antagonism of blockade [6, 8, 12]. Contemporary literature has repeatedly shown that relying only on clinical signs or qualitative assessment may fail to detect incomplete recovery, and a study confirmed that postoperative residual neuromuscular blockade still

occurs in routine practice when neuromuscular management is suboptimal [12]. It was specifically questioned whether quantitative confirmation after recommended-dose sugammadex can be omitted and concluded that the issue remains clinically relevant, reinforcing the principle that pharmacologic reversal should complement rather than replace monitoring [12]. In practical terms, our findings support a dual strategy of evidence-based dosing of sugammadex plus objective monitoring of TOF recovery before extubation, as this combination offers the best opportunity to minimize residual weakness and respiratory compromise [6].

The sample size was small, which limits precision and may reduce the ability to detect uncommon adverse effects or subgroup differences. The study was conducted at a single tertiary centre and included only ASA I and II adults undergoing elective procedures, so the results should not be generalized without caution to elderly patients, paediatric populations, emergency surgery, major organ dysfunction, or other high-risk groups. In addition, although clinically important endpoints such as recovery time, blockade duration, and extubation time were examined, the study did not evaluate patient-centered recovery quality, post-anaesthesia care unit stay, postoperative pulmonary complications, or economic outcomes. Future multicentre studies with larger and more diverse cohorts should therefore compare rocuronium–sugammadex and vecuronium–sugammadex strategies not only for speed of reversal but also for respiratory outcomes, recovery quality, institutional efficiency, and economic feasibility. Despite these limitations, the present study adds useful prospective clinical evidence showing that sugammadex is effective and safe for reversal of both aminosteroidal blockers, while the rocuronium–sugammadex combination provides a faster and more favorable recovery profile than the vecuronium–sugammadex combination in routine elective anaesthesia practice.

**Conclusion:** Sugammadex was effective and safe in reversing neuromuscular blockade induced by both rocuronium and vecuronium in adult patients undergoing elective surgery under general anaesthesia. However, reversal was significantly faster in the rocuronium group, as shown by shorter recovery time to TOF ratio  $\geq 0.9$ , shorter duration of blockade, and earlier extubation. Adverse events were minimal and comparable in both groups, with no residual neuromuscular blockade or severe hypersensitivity reactions. These findings suggest that although sugammadex reliably reverses both aminosteroidal neuromuscular blockers, the rocuronium–sugammadex combination may offer a more favorable recovery profile in routine anaesthetic practice.

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