

Incidence of Postoperative Residual Neuromuscular Blockade at the Postanesthesia Care Unit Following General Anesthesia

Sarinya Chanthawong^{ID}, M.D., Thidamas Apithambundit^{ID}, M.D., Netinai Chaimala^{ID}, B.N.S., Sangmukda Saras^{ID}, B.N.S., Thanat Yotepanya^{ID}, M.D.*, Saranyoo Nonphiaraj^{ID}, M.D.

Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, Khon Kaen 40002, Thailand.

Residual Neuromuscular Blockade (RNMB) at the Postanesthesia Care Unit

RNMB: Train of Four (TOF) ratio < 0.9

40.8 %

154 out of 377 patients



A prospective observational study: Srinagarind Hospital, Khon Kaen University
377 patients after general anesthesia with neuromuscular blocking agents



ADVERSE EVENTS

6.6%

HYPOXEMIA 2.9%

TACHYPNEA 3.7%



Potential risk factor for RNMB



Ophthalmic surgery

Adjusted OR 2.44 (95% CI 1.16–4.87)

SCAN FOR
FULL TEXT



SMJ

**SIRIRAJ
MEDICAL
JOURNAL**

Chanthawong, et al. *Siriraj Med J* 2025;77(7):496–504.

©Siriraj Medical Journal. All rights reserved. Graphical abstract by S Chanthawong

*Corresponding author: Thanat Yotepanya

E-mail: thanyo@kku.ac.th

Received 27 December 2024 Revised 27 February 2025 Accepted 27 February 2025

ORCID ID: <http://orcid.org/0009-0006-2973-4368>

<https://doi.org/10.33192/smj.v77i7.272875>



All material is licensed under terms of
the Creative Commons Attribution 4.0
International (CC-BY-NC-ND 4.0)
license unless otherwise stated.

ABSTRACT

Objective: This study aimed to investigate residual neuromuscular blockade (RNMB), respiratory adverse events, and identify risk factors for RNMB.

Material and Methods: A prospective observational study enrolled 377 elective adult patients with American Society of Anesthesiologists (ASA) classifications 1–3 who underwent GA with NMBAs. At the conclusion of surgery, endotracheal tubes were removed once clinical extubation criteria were met. The Train-of-Four (TOF) ratio was immediately measured upon the patients' arrival in the postanesthesia care unit (PACU), with RNMB defined as a TOF ratio < 0.9. Respiratory adverse events were documented.

Results: The incidence of RNMB was 40.8% upon PACU arrival, with a median TOF ratio of 0.92 (interquartile range [IQR], 0.85–0.98). Cisatracurium was the primary NMBA used (98.1%). The incidence of respiratory adverse events was 6.6%, including hypoxemia (2.9%) and tachypnea (3.7%). No cases of reintubation or unplanned ICU admission occurred. The ophthalmologic surgery emerged as the only significant risk factor for RNMB, adjusted OR 2.44 (95% CI, 1.16–4.38, $p = 0.02$).

Conclusion: The incidence of RNMB after GA in the PACU was common, though no serious adverse events were observed. The type of surgery was identified as the sole significant risk factor for RNMB.

Keywords: Residual neuromuscular blockade; NMBAs; muscle relaxant; postanesthesia care unit; train-of-four (Siriraj Med J 2025; 77: 496–504)

INTRODUCTION

Neuromuscular blocking agents (NMBAs) are essential components of most anesthetic techniques. They are used to facilitate tracheal intubation, reduce airway injury, and maintain muscle relaxation, thereby promoting the success of surgical procedures, particularly in thoracic and abdominal surgeries.^{1,2} However, several studies have reported that the effects of NMBAs often persist in the post-anesthesia care unit (PACU), even after the administration of acetylcholinesterase inhibitors,³ indicating that these patients may experience residual neuromuscular blockade (RNMB).

RNMB is linked to postoperative pulmonary complications such as hypoxemia, hypercapnia, upper airway obstruction, respiratory muscle weakness, dyspnea, the need for airway equipment, reintubation, pneumonia, pharyngeal muscle dysfunction, aspiration, and atelectasis.^{4,5} These complications increase morbidity and mortality within the first 24 hours postoperatively⁶ and may delay discharge from the PACU.⁷

According to the 2020 guidelines on muscle relaxants and reversal in anesthesia published by the French Society of Anaesthesia & Intensive Care Medicine (SFAR), quantitative monitoring of the adductor pollicis muscle of the ulnar nerve is likely recommended for diagnosing RNMB.⁸ Achieving a Train-of-Four (TOF) ratio of ≥ 0.9 can eliminate the possibility of RNMB. The guidelines also recommend administering an acetylcholinesterase inhibitor once a measured TOF ratio at the adductor pollicis muscle is ≥ 0.2 .

Several studies^{7,9–13} emphasize the importance of appropriate administration of neuromuscular blocking agents (NMBAs) and their reversal agents. Specifically, the use of neuromuscular monitoring is crucial to prevent the incidence and adverse effects of RNMB. In current practice at our center, clinical criteria are used at the end of surgery before extubation. If these clinical extubation criteria are not met or RNMB is suspected, a TOF ratio is measured. An additional reversal agent is considered if the TOF ratio is consistent with RNMB.

Due to the lack of data on the incidence of RNMB and the appropriate administration of NMBAs and their reversal agents in our tertiary health care center, we aimed to investigate the incidence of RNMB upon PACU arrival and to identify associated risk factors. The results of this study could contribute to a new database and be analyzed to improve our institution's patient management guidelines.

MATERIAL AND METHODS

This was a prospective observational study approved by the Ethics Committee in Human Research, Khon Kaen University (HE651283). Data collection occurred from August 2022 to July 2023. Patients aged over 18 years with American Society of Anesthesiologists (ASA) classification I–III who underwent elective surgery with general anesthesia using NMBAs were enrolled. Exclusion criteria included patients with pre-existing neuromuscular diseases such as myasthenia gravis, Guillain-Barre syndrome which could interfere with TOF responses^{14,15}, undergoing

airway surgery, sensitive population such as pregnant patients, and patients with preoperative respiratory conditions such as hypoxemia ($\text{SpO}_2 < 90\%$), tachypnea (respiratory rate > 20 breaths/min), use of oropharyngeal or nasopharyngeal airways, retention of an endotracheal tube, use of accessory respiratory muscles, or pneumonia. Additionally, patients who declined participation were excluded.

Patients who met the inclusion criteria were selected and informed about the details of the study. On the day of surgery, general anesthesia with NMBA was conducted according to routine practice determined by the attending anesthesiologist. At the end of the procedure, reversal agents (either neostigmine at 0.05 mg/kg with atropine at 0.02 mg/kg or sugammadex at 2 mg/kg) were administered. Tracheal extubation was performed once the patient met all clinical extubation criteria which included hemodynamic stability, spontaneous breathing with tidal volume > 5 mL/kg, $\text{SpO}_2 > 94\%$, $\text{EtCO}_2 < 50$ mmHg, intact gag reflex, sustained head lift for 5 seconds, hand grip, and following commands. During transfer to the PACU following extubation, patients received supplemental oxygen at 6–8 L/min via an oxygen mask with a reservoir bag.

Upon arrival at the PACU, the acceleromyography TOF-Watch® SX (Organon) was applied by the PACU nurse anesthetist who was not involved in this study, within the first 5 minutes to measure the TOF ratio. TOF stimulations at 30 mA were applied to the ulnar nerve twice, with a 15-second interval, and TOF responses were measured at the adductor pollicis muscle. The final TOF ratio was calculated as the average of the two values obtained. If the discrepancy between the two readings was ≥ 0.2 , an additional TOF stimulation was performed, and the average of the two closest TOF ratios was used as the final TOF ratio. All study procedures were conducted without interfering with standard PACU care.

Patients' demographic data, including sex, age, weight, height, ASA physical status, and underlying diseases, were collected. Perioperative data such as type of surgery, anesthesia duration, type, dose, and interval of NMBA, type and dose of reversal agents, and body temperature in the operating room and PACU were recorded. RNMB was diagnosed if the average TOF ratio was < 0.9 and defined as severe RNMB if the average TOF ratio was < 0.7 . Respiratory adverse events, including hypoxemia, tachypnea, the need for airway support, use of accessory respiratory muscles, reintubation, and unplanned ICU admission, were documented within 1 hour postoperatively.

Sample size calculation

The sample size was calculated using a formula for estimating the proportion in an infinite population, based on the study by Ismail Aytac et al.¹⁴, which reported an RNMB incidence of 43%. A 95% confidence level ($\alpha = 0.05$) and a 5% margin of error were used. The final calculated sample size was 377 patients.

Statistical analysis

Data analysis was conducted using STATA version 18. Categorical data were analyzed using Fisher's exact test or the Chi-squared test and presented as numbers and percentages. Continuous data which normally distributed were presented as mean with standard deviation (SD) and analyzed using Student's t-test while non-normally distributed data were presented as median with interquartile range (IQR) and analyzed using Wilcoxon rank-sum test. A p-value of < 0.05 was considered statistically significant. Univariate and multivariate logistic regression analyses were performed to identify risk factors for RNMB.

RESULTS

During the study period, 377 patients were enrolled, the majority of whom were female (66%). Participants' demographic data are shown in Table 1. The most common ASA classification was II (49.1%), and the most frequently performed procedure was gynecologic surgery (24.1%). The average patient age was 52 years. The mean anesthesia duration was 154.1 ± 64.7 minutes. Cisatracurium was the most frequently used NMBA (98.1%). There were 3 patients received a combination of NMBA: 2 patients received rocuronium and cisatracurium, and 1 patient received cisatracurium and atracurium. The average time between the last NMBA dose and administration of a reversal agent was 52.4 ± 21.5 minutes. The median TOF ratio was 0.92 (IQR: 0.85, 0.98). All patients received a reversal agent prior to extubation, with neostigmine being the most commonly used (99.7%).

The incidence of RNMB upon arrival at the PACU was 40.8% (154 out of 377 patients), as illustrated in Fig 1. Two of these patients received a combination of NMBA: one patient received rocuronium and cisatracurium, and another patient received cisatracurium and atracurium. The incidence rates of RNMB were 40.8% for cisatracurium, 40% for atracurium, and 60% for rocuronium. Severe RNMB was observed in 5.6% of patients (21 out of 377), with 20 patients having received cisatracurium and 1 patient having received a combination of rocuronium and cisatracurium. (Fig 2)

TABLE 1. Clinical features of patients who underwent elective surgery with general anesthesia using neuromuscular blocking agents (n=377).

Characteristics	Study population (n=377)
Female*	249 (66%)
Age (years)**	52.3 ± 15.3
Weight (kg)**	62.6 ± 12.4
Height (cm)**	160.0 ± 10.0
BMI (kg/m ²)**	24.3 ± 4.4
ASA classification*	
I	165 (43.7%)
II	185 (49.1%)
III	27 (7.2%)
Surgery type*	
Gynecologic	91 (24.1%)
Otolaryngologic	74 (19.6%)
Ophthalmologic	72 (19.1%)
General	72 (19.1%)
Orthopedic	51 (13.5%)
Plastic	13 (3.5%)
Neurologic	3 (0.8%)
Maxillofacial	1 (0.3%)
Anesthetic time (min)**	154.1 ± 64.7
Temperature in OR (°C)***	36.0 (35.7, 36.3)
Temperature in PACU (°C)***	36.4 (36.2, 36.6)
Neuromuscular blocker used*	
Cisatracurium	370 (98.1%)
Atracurium	5 (1.3%)
Rocuronium	5 (1.3%)
Reversal agent used*	
Neostigmine	376 (99.7%)
Sugammadex	1 (0.3%)
Dosage of neuromuscular blocker (mg/kg)**	
Cisatracurium	0.20 ± 0.08
Atracurium	0.70 ± 0.43
Rocuronium	0.91 ± 0.14
Dosage of reversal agent (mg/kg)**	
Neostigmine	0.04 ± 0.01
Interval from last dose NMB administration (mins)**	52.4 ± 21.5
TOF ratio***	0.92 (0.85, 0.98)

* = number (%), ** = mean ± SD, *** = median (IQR)

Abbreviations: BMI = body mass index; ASA = American society of Anesthesiologists; OR = operating rooms, PACU = post anesthesia care unit; TOF = train of four

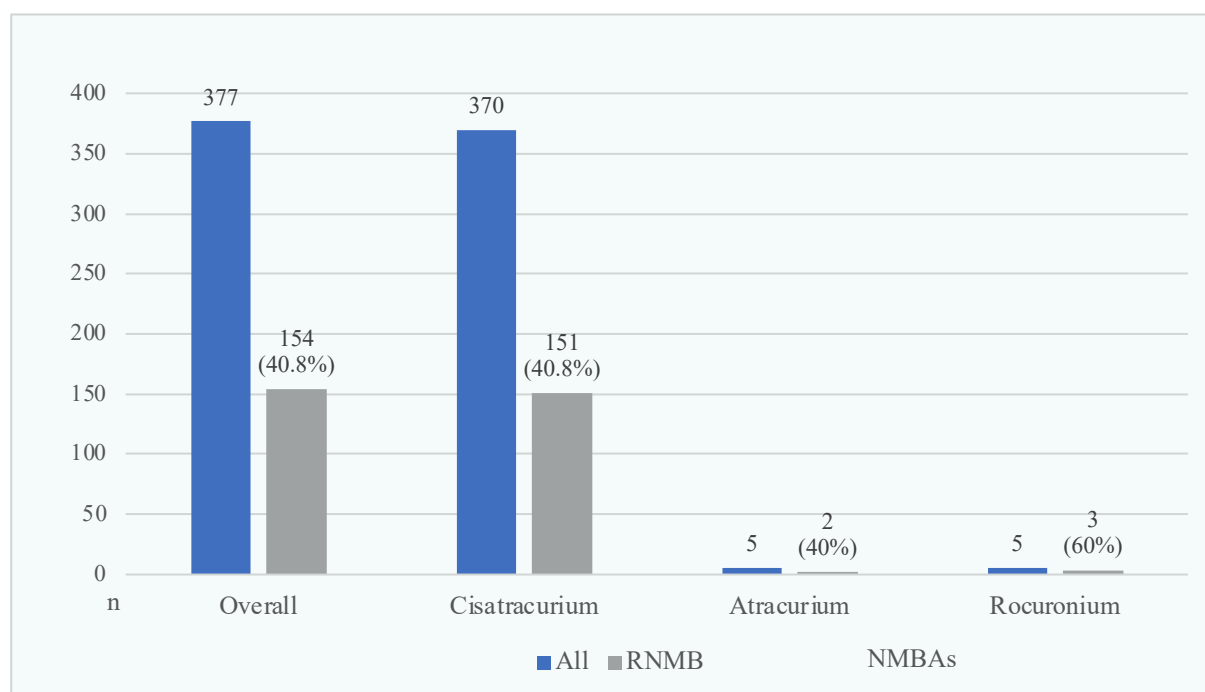


Fig 1. Incidence of residual neuromuscular blockade in patients who underwent elective surgery with general anesthesia using neuromuscular blocking agents.

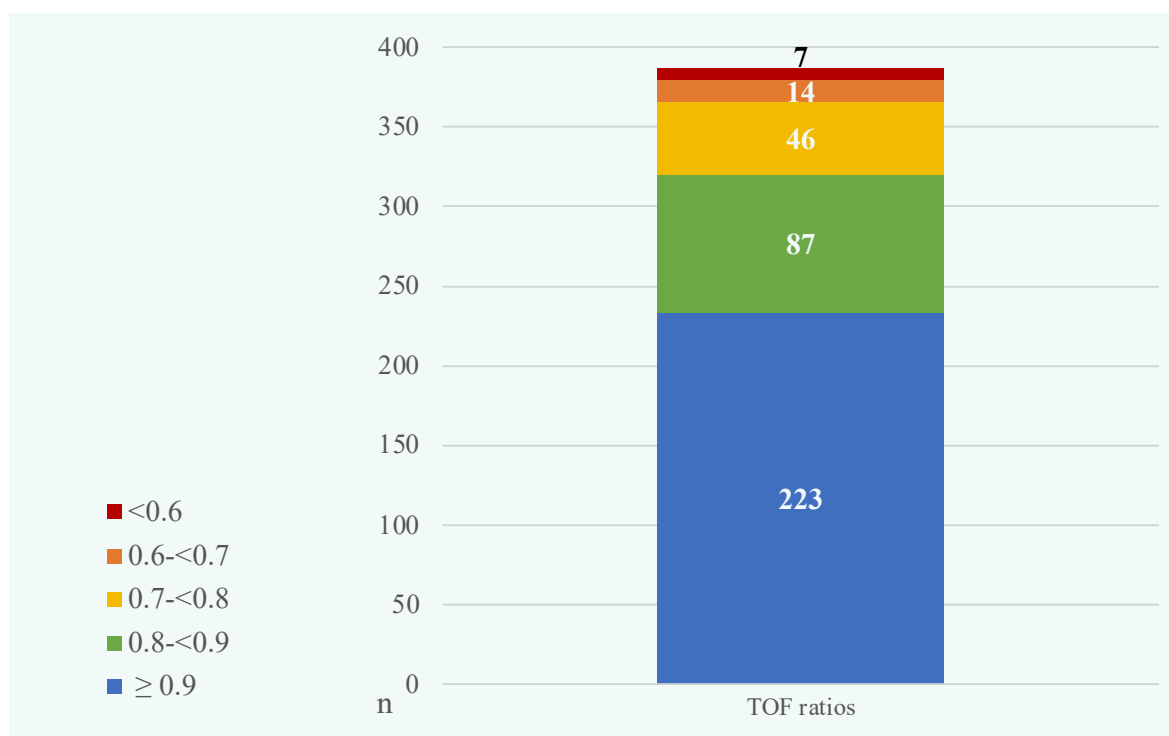


Fig 2. Number of patients in each TOF ratio range.

The incidence of adverse events within the first hour postoperatively was 6.6% (25 patients). Adverse respiratory events included hypoxemia in 11 patients (2.9%) and tachypnea in 14 patients (3.7%). All adverse events occurred in patients who had received cisatracurium. Hypoxemia was managed with low-flow oxygen delivered via nasal cannula or mask with a reservoir bag. No

cases of reintubation or unplanned ICU admission were reported.

Univariable and multivariable analyses were conducted to identify potential risk factors for residual neuromuscular blockade, including sex, age, BMI > 30 kg/m², ASA classification I-III, chronic kidney disease (CKD) stage 4-5, type of surgery, time between the last

NMBA dose and reversal agent administration, anesthesia duration, and hypothermia upon arrival at the PACU. The analysis revealed that ophthalmologic surgery was the only significant risk factor for RNMB, adjusted OR of 2.44 (95% CI: 1.16 to 4.87, $p=0.02$).

DISCUSSION

Incidence of residual neuromuscular blockade

This study found an incidence of RNMB of 40.8%, despite all patients receiving a reversal agent. This is comparable to an observational study by Aytac et al.,¹⁶ which included 415 patients undergoing anesthesia with intermediate-acting NMBAs and reported an overall RNMB incidence of 43%. In that study, TOF ratios < 0.9

were observed in 42% of patients receiving vecuronium, 52% of those receiving rocuronium, and 30% of those receiving atracurium. Additionally, the incidence of RNMB was 46.3% among patients who received neostigmine at a mean dose of 20 ± 10 mcg/kg. We hypothesize that the lower incidence of RNMB in our study may be attributed to the higher mean dose of neostigmine used (40 ± 10 mcg/kg). Furthermore, there was a difference in the type of NMBAs used, with 98.1% of patients in our study receiving cisatracurium.

A meta-analysis by Carvalho et al.¹⁷ in 2020, which included 53 studies and 12,664 patients, reported the incidence of RNMB based on TOF ratios measured at or post-extubation of <0.7, <0.9, or <1.0. Specifically

TABLE 2. Correlation between patient/anesthesia/surgery-related factors and residual neuromuscular blockade.

Variables	Crude OR 95% CI	p-value	Adjusted OR 95% CI	p-value
Male	0.73 (0.47, 1.14)	0.16	0.66 (0.38, 1.14)	0.13
Advanced age	1.26 (0.77, 2.06)	0.35	1.16 (0.68, 1.20)	0.58
BMI ≥ 30 kg/m ²	0.75 (0.33, 1.73)	0.50	0.65 (0.25, 1.68)	0.37
Surgery type				
Ophthalmologic	2.36 (1.20, 4.64)	0.01*	2.44 (1.16, 4.87)	0.02*
Gynecologic	1.79 (0.94, 3.40)	0.22	1.42 (0.68, 2.96)	0.35
Otolaryngologic	1.52 (0.78, 2.98)	0.07	1.32 (0.65, 2.67)	0.44
Neurologic	1.00 (0.09, 11.59)	> 0.99	1.15 (0.10, 13.74)	0.91
Orthopedic	0.68 (0.31, 1.52)	0.35	0.62 (0.27, 1.40)	0.25
Plastic	0.36 (0.07, 1.77)	0.47	0.36 (0.07, 1.87)	0.22
CKD stage 4-5	0.58 (0.09, 3.72)	0.65	0.87(0.25, 2.95)	0.82
Hypothermia (BT < 36°C)	1.48 (0.92, 2.40)	0.11	1.46 (0.86, 2.46)	0.16
Type of muscle relaxant				
Cisatracurium	0.92 (0.20, 4.17)	> 0.99	0.75 (0.03, 19.67)	0.71
Atracurium	0.96 (0.16, 5.84)	> 0.99	0.88 (1.22, 6.35)	0.90
Rocuronium	2.20 (0.36, 13.3)	> 0.40	2.67 (0.25, 27.65)	0.41
Reversal dose (mcg/kg)	0.15 (<0.01, >99)	0.62	0.08 (0.00, 532)	0.75
Time between the last dose of NMBAs and reversal agents < 30 min	0.76 (0.31, 1.84)	0.54	0.91 (0.35, 2.34)	0.84
Anesthetic time > 240 min	0.47 (0.20, 1.09)	0.16	0.48 (0.19, 1.25)	0.22

* p-value < 0.05 is considered statistically significant

Abbreviations: BMI = body mass index; CKD = chronic kidney disease; BT = body temperature; NMBAs = neuromuscular blocking agents

focusing on a TOF ratio of <0.9 , the study found that the RNMB incidence in adult patients undergoing elective surgery under general anesthesia with intermediate-acting NMBAs was 33.1% in the no-neuromuscular-monitoring (NMM) group, 30.6% in the qualitative NMM group (peripheral nerve stimulation), and 11.5% in the quantitative NMM group (TOF ratio monitoring). The study concluded that patients monitored with TOF had a significantly lower incidence of RNMB compared to those monitored qualitatively or not monitored at all. Our findings are comparable to those of the no-NMM group.

An observational study conducted in Thailand by Khamtuikrua et al.¹⁸ in 2017, which included 209 patients in a similar setting to our study, reported an incidence of RNMB upon PACU arrival of 53.1%, higher than the incidence observed in our study. Despite the similarity in patient populations, a possible explanation for this difference is that 3.3% of patients in their study did not receive a reversal agent. In contrast, all patients in our study received reversal agents, with 99.7% receiving neostigmine and 0.3% receiving sugammadex. Since our center does not routinely employ TOF monitoring, we administer a reversal agent to most patients to reduce the incidence of RNMB.

Adverse respiratory events

In this study, we found that 45.5% of the 11 patients with hypoxemia had RNMB. This result contrasts with the findings of Aytac et al.¹⁶, where 82.4% of patients with hypoxemia had RNMB. Respiratory complications were more frequent among patients with a TOF ratio <0.7 , with 42.6% requiring airway support. Additionally, Murphy et al.¹⁹ reported that patients experiencing critical respiratory events after general anesthesia had a higher incidence of RNMB.

Interestingly, no major adverse events, such as reintubation or unplanned ICU admission, were observed. The adverse events identified were hypoxemia and tachypnea, which were successfully managed with conventional low-flow oxygen supplementation. We recorded only the incidence of these adverse respiratory events and did not explore their underlying causes, which may have been multifactorial.

Therefore, despite the incidence of RNMB being 40.8%, our current practice—which includes the use of clinical extubation criteria, administration of reversal agents to most patients, and selective use of neuromuscular monitoring (e.g., in patients with neuromuscular diseases or delayed awakening)—appears to be relatively safe for our general patient population, as no major adverse events were recorded.

Risk factors for residual neuromuscular blockade

We found that only the type of surgery was significantly associated with RNMB, with ophthalmologic surgery showing the highest odds ratio. A possible explanation for this finding is that 40% (29 out of 72) of patients undergoing ophthalmologic surgery were of advanced age, a group known to be at increased risk for RNMB.²⁰ Additionally, we observed that 65% of older adults who underwent ophthalmologic surgery experienced RNMB. This is consistent with a recent study by Murphy et al.²¹, which suggested that RNMB may be more common in older adults (57%) compared to younger patients (30%). Therefore, it is recommended that a combination of TOF monitoring and clinical assessments be used for these patients.²²

Aytac et al.¹⁶ identified female sex, ASA physical status class III, and short anesthesia duration as risk factors for RNMB, which differed from our findings. Additionally, Carvalho et al.¹⁷ reported that the use of sugammadex as a reversal agent was associated with a lower rate of RNMB compared to neostigmine. However, we were unable to investigate differences between neostigmine and sugammadex in our study, as it was only administered to a single patient.

Khamtuikrua et al.¹⁸ reported that an increase in age by 10 years, a time interval of less than 30 minutes between the last dose of NMBA and administration of a reversal agent, and hypothermia (body temperature $<36^{\circ}\text{C}$) were significant risk factors for RNMB.

Limitations

Since our primary outcome was to assess the incidence of RNMB, we calculated the sample size based on the proportion reported in the previous study by Aytac et al.¹⁶ However, our sample size may have been insufficient to identify all possible risk factors for RNMB. Additionally, in order to identify RNMB, we did not use clinical assessments such as hand grip strength combined with the TOF ratio, which would have been helpful in determining early neuromuscular impairment.²³ To properly identify risk factors, further studies with an appropriately powered sample size, a multi-center study, or a combination of clinical assessment and TOF for RNMB diagnosis may be required.

CONCLUSION

The incidence of RNMB in the PACU following general anesthesia was high, even with the use of reversal agents. However, no serious respiratory adverse events were observed. Among the potential risk factors, ophthalmic surgery was the only factor significantly associated with RNMB.

Clinical implications

1. What is already known on this topic

Residual neuromuscular blockade, defined as a TOF ratio < 0.9, can lead to postoperative pulmonary complications and increase both morbidity and mortality. Although neuromuscular monitoring is recommended to exclude residual neuromuscular blockade, it is not routinely used in our center.

2. What this study adds

The incidence of RNMB upon arrival at the PACU was 40.8%, despite the administration of a reversal agent. No major respiratory adverse events were observed. Ophthalmic surgery was identified as a risk factor for RNMB. Therefore, routine TOF monitoring is recommended for patients at risk of RNMB, specifically those undergoing ophthalmic surgery, to enhance safety.

Data Availability Statement

The data of this study are available upon reasonable request.

ACKNOWLEDGMENTS

We would like to thank Dr. Dylan Southard for editing this manuscript via the KKU Publication Clinic (Thailand).

DECLARATION**Grants and Funding Information**

This work is not funded by any external resources.

Conflict of Interest

The authors declare no conflict of interest.

Registration Number of Clinical Trial

This was a prospective observational study approved by the Ethics Committee in Human Research, Khon Kaen University (HE651283)

Author Contributions

Conceptualization and methodology, S.C., T.A., and T.Y.; data collection, T.A., N.C., and S.S.; formal analysis, S.C., T.A., and T.Y.; writing – original draft, S.C., T.A.; writing – review and editing, S.C., T.Y., and S.N. All authors have read and agreed to the published version of the manuscript.

Use of Artificial Intelligence

None

REFERENCES

1. Baillard C, Clec'h C, Catineau J, Salhi F, Gehan G, Cupa M, et al. Postoperative residual neuromuscular block: a survey of management. *Br J Anaesth*. 2005;95(5):622–6.
2. Yu B, Ouyang B, Ge S, Luo Y, Li J, Ni D, et al. Incidence of postoperative residual neuromuscular blockade after general anesthesia: a prospective, multicenter, anesthetist-blind, observational study. *Curr Med Res Opin*. 2016;32(1):1–9.
3. Plaud B, Debaene B, Donati F, Marty J. Residual paralysis after emergence from anesthesia. *Anesthesiology*. 2010;112(4):1013–22.
4. Murphy GS, Szokol JW, Marymont JH, Greenberg SB, Avram MJ, Vender JS. Residual neuromuscular blockade and critical respiratory events in the postanesthesia care unit. *Anesth Analg*. 2008;107(1):130–7.
5. Grosse-Sundrup M, Henneman JP, Sandberg WS, Bateman BT, Uribe JV, Nguyen NT, et al. Intermediate acting non-depolarizing neuromuscular blocking agents and risk of postoperative respiratory complications: prospective propensity score matched cohort study. *BMJ*. 2012;345:e6329.
6. Arbous MS, Meursing AEE, van Kleef JW, de Lange JJ, Spoormans HHAJM, Touw P, et al. Impact of anesthesia management characteristics on severe morbidity and mortality. *Anesthesiology*. 2005;102(2):257–68; quiz 491–2.
7. 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):304–9.
8. Plaud B, Baillard C, Bourgain JL, Bouroche G, Desplanque L, Devys JM, et al. Guidelines on muscle relaxants and reversal in anaesthesia. *Anaesth Crit Care Pain Med*. 2020;39(1):125–42.
9. Murphy GS, Brull SJ. Residual neuromuscular block: lessons unlearned. Part I: definitions, incidence, and adverse physiologic effects of residual neuromuscular block. *Anesth Analg*. 2010;111(1):120–8.
10. Brull SJ, Murphy GS. Residual neuromuscular block: lessons unlearned. Part II: methods to reduce the risk of residual weakness. *Anesth Analg*. 2010;111(1):129–40.
11. Murphy GS. Residual neuromuscular blockade: incidence, assessment, and relevance in the postoperative period. *Minerva Anesthesiol*. 2006;72(3):97–109.
12. Berg H, Roed J, Viby-Mogensen J, Mortensen CR, Engbaek J, Skovgaard LT, et al. Residual neuromuscular block is a risk factor for postoperative 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.
13. Esteves S, Martins M, Barros F, Barros F, Canas M, Vitor P, et al. Incidence of postoperative residual neuromuscular blockade in the postanesthesia care unit: an observational multicentre study in Portugal. *Eur J Anaesthesiol*. 2013;30(5):243–9.
14. Moningi S, Durga P, Mantha S, Ramachandra G. Train of Four Responses in Paretic Limbs. *Journal of Neurosurgical Anesthesiology* [Internet]. 2009;21(4). Available from: https://journals.lww.com/jnsa/fulltext/2009/10000/train_of_four_responses_in_paretic_limbs.9.aspx
15. Thongsing A, Likasitwattanakula S, Netsuwan T, Sanmaneechai O. Pediatric Neuromuscular Diseases Prevalence in Siriraj Hospital, Thailand's Largest Tertiary Referral Hospital. *Siriraj Med J*. 2020;72(2):125–31.

16. Aytac I, Postaci A, Aytac B, Sacan O, Alay GH, Celik B, et al. Survey of postoperative residual curarization, acute respiratory events and approach of anesthesiologists. *Braz J Anesthesiol.* 2016;66(1):55–62.
17. 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.
18. Khamtuikrua C, Suksompong S, Rhoopanwong S, Sangsab P, Chaikittisilpa N, Bormann B von. Risk Factors for Residual Neuromuscular Blockade after General Anesthesia. *J Med Assoc Thai.* 2017;100(Suppl 7):S75-S84.
19. Murphy GS, Szokol JW, Marymont JH, Greenberg SB, Avram MJ, Vender JS, et al. Intraoperative acceleromyographic monitoring reduces the risk of residual neuromuscular blockade and adverse respiratory events in the postanesthesia care unit. *Anesthesiology.* 2008;109(3):389–98.
20. Lee LA, Athanassoglou V, Pandit JJ. Neuromuscular blockade in the elderly patient. *J Pain Res.* 2016;9:437–44.
21. Murphy GS, Szokol JW, Avram MJ, Greenberg SB, Shear TD, Vender JS, et al. Residual Neuromuscular Block in the Elderly: Incidence and Clinical Implications. *Anesthesiology.* 2015; 123(6):1322–36.
22. Sagir O, Yucesoy Noyan F, Koroglu A, Cicek M, Ilksen Toprak H. Comparison between the Effects of Rocuronium, Vecuronium, and Cisatracurium Using Train-of-Four and Clinical Tests in Elderly Patients. *Anesth Pain Med.* 2013;2(4):142–8.
23. Tantibhaedhyangkul P, Kuptniratsaikul V, Tosayanonda O. Grip and Quadriceps Strength: Normative Values in the Thai Population. *Siriraj Med J.* 2020;53(4):224–30.