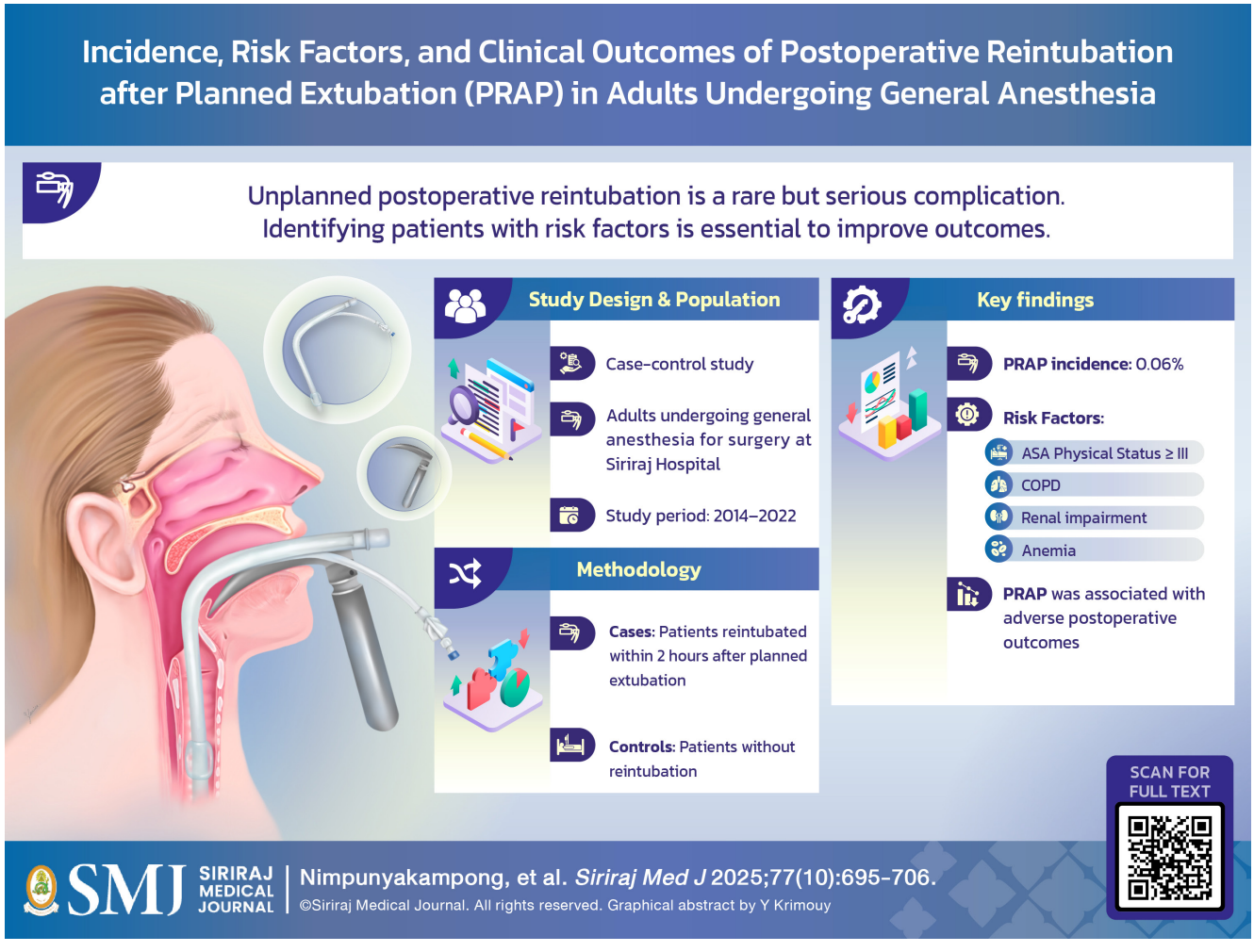
Incidence, Risk Factors, and Clinical Outcomes of Postoperative Reintubation after Planned Extubation in Adults Undergoing General Anesthesia: A Single-center Experience

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ABSTRACT

Objective: Postoperative reintubation after planned extubation (PRAP) is a complication following general anesthesia. This study aimed to determine the incidence, risk factors, and outcomes in a tertiary-care university hospital.

Materials and Methods: A retrospective case-control study was conducted between 2014 and 2022. The PRAP group included patients requiring reintubation within 2 h after planned extubation following general anesthesia, while the control group included patients who did not require reintubation. Cases and controls were matched in a 1:3 ratio, with time-matched controls randomly selected within 2 weeks. Descriptive statistics and logistic regression were utilized for analysis.

Results: Of 139,103 patients, 88 PRAP cases were identified, yielding an incidence of 0.06% (95% Confidence Interval [CI], 0.05–0.08). Multivariate analysis revealed independent risk factors associated with PRAP: the American Society of Anesthesiologists Physical Status (ASA) ≥ III (adjusted odds ratio [aOR], 2.72; 95% CI, 1.58–4.66; $P < 0.001$), hemoglobin < 12 g/dL (aOR, 1.76; 95% CI, 1.02–3.01; $P = 0.041$), creatinine clearance < 60 mL/min (aOR, 3.38; 95% CI, 2.16–5.30; $P < 0.001$), and chronic obstructive pulmonary disease (COPD) (aOR, 18.73; 95% CI, 1.60–219.22; $P = 0.020$). PRAP was associated with increased 30-day mortality, cardiac arrest, and prolonged length of hospital and intensive care unit stay (all, $P < 0.001$).

Conclusion: The incidence of PRAP was 0.06%. Independent risk factors associated with PRAP were ASA, hemoglobin, creatinine clearance, and COPD. PRAP is associated with adverse postoperative outcomes, highlighting the need for preventive strategies and careful perioperative management.

Keywords: Anesthesia complication; extubation; mortality; postoperative complication; postoperative reintubation; risk factors (Siriraj Med J 2025; 77: 695-706)

INTRODUCTION

Postoperative reintubation after planned extubation (PRAP) is a severe complication of general anesthesia involving endotracheal intubation. PRAP is associated with significantly higher rates of postoperative complications—such as cardiac and pulmonary complications, prolonged hospital stays, and increased mortality.[1-3] Despite established extubation protocols and preventive strategies, PRAP remains a persistent issue.[4]

Reported PRAP incidence rates vary widely, ranging from 0.06% to 14.8%.[5-11] This variability may stem from differences in study populations and definitions of PRAP. While some studies define PRAP occurrences within the post-anesthesia care unit (PACU),[5-7,10,11] others consider later events in surgical wards.[8,9] In Thailand, two-decade-old studies reported PRAP incidences of 0.14% and 0.27% in PACU settings,[7,10] but these findings may not reflect current anesthesia practices. Updated data on PRAP incidence is crucial, as it serves as an indicator of anesthesia service quality and aligns with patient safety goals.[12]

Several risk factors for PRAP have been identified, including extreme age, chronic obstructive pulmonary disease (COPD), prolonged surgical duration, a higher American Society of Anesthesiologists (ASA) physical status, and the use of certain neuromuscular blocking agents.[13] However, findings vary across studies, likely due to differences in patient populations, surgical types, and institutional practices. Furthermore, most of these identified risk factors are non-modifiable, either patient-related or surgery-related. Understanding the risk factors within a specific institution and exploring potentially modifiable anesthesia-related factors is crucial for optimizing perioperative care and anesthetic management to reduce the occurrence of PRAP.[14]

This study aimed to evaluate the incidence of PRAP in a tertiary-care university hospital in Thailand. Additionally, it aimed to identify associated risk factors for and adverse outcomes. The focus was on immediate PRAP occurring within the first two postoperative hours, as such events are typically related to anesthetic management.[15] While PRAP may also occur later during hospitalization, these later cases are often influenced by factors unrelated to anesthesia.[9,16] The study sought to explore modifiable anesthesia-related risk factors that could be implemented in future anesthesia practices to reduce the occurrence of PRAP.

MATERIALS AND METHODS

A retrospective case-control study was conducted at Siriraj Hospital, a tertiary-care center in Bangkok, Thailand. The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and was approved by the Siriraj

Institutional Review Board (COA no. Si 621/2022). Informed consent was not required due to the retrospective nature and anonymization of data. Data was extracted from electronic records spanning January 1, 2014, and August 24, 2022.

Study participants

This study included adult patients aged ≥ 18 yr undergoing any types of surgery under general anesthesia with endotracheal intubation. The total number of these patients during the study period was obtained from the anesthesiology department's records. Anesthetic records at the study site comprised three components: preoperative, intraoperative, and postoperative data. Reintubation events were retrieved through the Anesthesiology's department postoperative dataset and considered as potential PRAP cases. PRAP was defined as reintubation occurring within 2 h following planned extubation. All potential PRAP cases were reviewed by anesthesiologists to exclude patients who were intubated before surgery, remained intubated postoperatively, had tracheostomies, or experienced accidental extubation. For the control group, patients who underwent postoperative extubation without reintubation were included. Cases and controls were matched at a 1:3 ratio, with controls randomly selected and time-matched within 2 weeks to minimize potential bias from temporal changes. Exclusion criteria for controls were similar to the cases. Anesthesiologists reviewed electronic medical records for both groups to collect data on preoperative, intraoperative, and anesthetic-related risk factors and postoperative outcomes.

Definitions of the variables

Preoperative variables included demographics (age, sex, and body mass index [BMI]), ASA physical status[17], comorbidities, and laboratory results. Respiratory conditions included COPD, asthma, obstructive sleep apnea, pleural effusion, and current smoking (defined as active smoking or cessation within 6 weeks before surgery). Recent pneumonia (within 30 days) and recent upper respiratory tract infections, characterized by symptoms such as cough, rhinorrhea, or sore throat within 2 weeks, were recorded.[18] Preoperative desaturation was defined as oxygen saturation < 95% on room air.[19] Cardiovascular conditions included congestive heart failure (CHF)[20] and myocardial infarction (MI).[21] Renal diseases encompass chronic kidney disease (CKD) and end-stage renal disease.[22] Central nervous system disorders included dementia, neuromuscular diseases, and altered consciousness (Glasgow Coma Score < 15). Hepatic disorders included ascites and cirrhosis. Systemic inflammatory response syndrome (SIRS), sepsis, and septic shock were noted.[23] Hematologic risk factors included bleeding disorders and recent blood transfusions (within 72 h before surgery). Laboratory parameters included preoperative serum creatinine, creatinine clearance, hemoglobin, white blood cell (WBC) count, and serum albumin levels. Elevated WBC or leukocytosis was classified when WBC count was ≥ 11,000 cells/μL.[24]

Operative variables included emergency surgery, operative duration, and surgical type (head and neck, airway, thoracic, cardiac, vascular, abdominal, orthopedic, neurosurgical, urological, and obstetric/gynecologic).

Anesthetic variables included the type and dosage of the last neuromuscular blocking agent (NMBA) and opioid, the reversal agent used, and the intervals between the last administration of NMBA or opioid and reversal. At our institution, atracurium, cisatracurium, and rocuronium are the primary NMBAs, with a typical clinical duration of 30–45 minutes.[25] Since neuromuscular blockade monitoring is not routinely used, reversal agents are administered based on clinical signs of recovery and the elapsed time since the last NMBA dose. For this study, early reversal was defined as the administration of a reversal agent within 45 minutes of the last NMBA dose.[26,27] We recognize that multiple factors, such as dose, duration, and renal clearance, influence the clinical duration of opioids, which in turn affect postoperative respiratory function and the risk of PRAP. To standardize our analysis, we applied a 45-minute cutoff for the last opioid dose before NMBA reversal.[27] Although this approach does not account for individual pharmacokinetic and pharmacodynamic variations, it provides a consistent reference for evaluating potential associations between opioid administration timing and PRAP.

Postoperative outcomes included 30-day mortality, cardiac arrest, hospital length of stay, intensive care unit (ICU) length of stay, and postoperative complications, such as pulmonary complications (pneumonia[28], mechanical ventilation > 48 h, and tracheostomy), cardiac complications (MI[29] and CHF[20]), renal complications (acute renal failure[30] and urinary tract infection[31]), neurologic complications (cerebrovascular accidents), thromboembolic events (deep vein thrombosis and pulmonary embolism), infections (wound infections[32], SIRS, sepsis, and septic shock[23]), and blood transfusions.

Sample size calculation

The primary outcome of PRAP incidence was used for sample size calculation. Based on a reported PRAP incidence of 0.14%[7] and using a two-sided significance level of 0.05 (type I error) and 90% power (type II error

= 10%), the minimum required sample size was 65,640 patients. An additional 10% was included to account for data loss.

For risk factor analysis, the sample size followed the rule of 10 events per variable. Based on seven previously identified risk factors,[5,6,33] the case group required at least 70 cases. Using a 3:1 control-to-case ratio, the final sample comprised 70 cases and 210 controls.

Statistical analysis

Patients were divided into PRAP and control groups. Continuous variables were presented as mean ± standard deviation or median (interquartile range [IQR]), depending on the data distribution, while categorical variables were reported as frequency (percentage). The Shapiro-Wilk test was used to assess the normality of continuous data. Univariable analysis was conducted to compare preoperative, intraoperative, anesthetic, and outcome variables. Continuous variables were compared using the Student's t test or Mann–Whitney U test depending on the distribution of data, while categorical variables were analyzed using the chi-square test or Fisher's exact test. Univariable logistic regression was conducted to estimate odds ratios for each variable. Pairwise exclusion was applied, whereby cases with missing data for a given variable were excluded only from the analysis of that specific variable. Variables with p values < 0.1 in univariable analysis were included in a stepwise backward multivariable logistic regression model to identify independent risk factors for PRAP. Collinearity was assessed using Variance Inflation Factor (VIF) and a correlation matrix, and only non-collinear variables were included in the model. A P value <0.05 was considered statistically significant. Data analysis was performed using Stata® statistics version 14 (StataCorp, College Station, Texas, USA).

RESULTS

Among 139,103 patients undergoing general anesthesia with endotracheal intubation at Siriraj Hospital between January 1, 2014, and August 24, 2022, 88 PRAP cases were identified, yielding an incidence rate of 0.06% (95% Confidence Interval [CI], 0.05–0.08). The control group comprised 264 randomly selected patients without PRAP. Fig 1 illustrates the study flow.

Univariable analysis revealed several preoperative risk factors for PRAP, including ASA physical status ≥ III, recent pneumonia, desaturation, CKD, altered consciousness, neuromuscular disease, cirrhosis, SIRS/sepsis, recent blood transfusions, creatinine clearance < 60 mL/min, hemoglobin < 12 g/dL, and WBC ≥ 11,000 cells/μL (Table 1). Intraoperative risk factors included emergency surgery, cardiovascular/thoracic surgery, neurosurgery, use of steroidal NMBAs, and time from last opioid administration to reversal < 45 min (Table 2). Multivariable analysis identified ASA physical status ≥ III, COPD, creatinine clearance < 60 mL/min, and hemoglobin < 12 g/dL as independent risk factors for PRAP (Table 3).

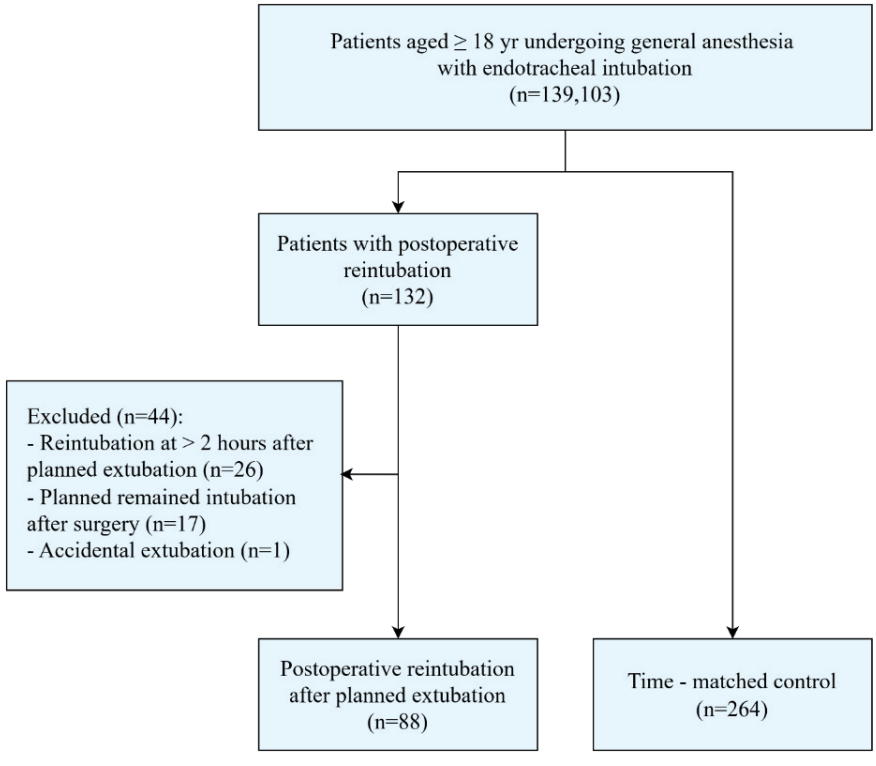


Fig 1. Study flow diagram.

TABLE 1. Univariate analysis of preoperative risk factors associated with postoperative reintubation after planned extubation (n = 352).

Variables	PRAP (n=88)	Control (n=264)	Crude OR (95% CI)	*P*-value
Demographic data				
Age, year, mean ± SD	62 ± 16	55 ± 19	-	**0.003**
< 65, n (%)	49 (55.7%)	184 (69.7%)	Reference	
≥ 65, n (%)	39 (44.3%)	80 (30.3%)	1.83 (1.11–3.01)	**0.017**
Gender (male), n (%)	46 (52.3%)	107 (40.5%)	1.61 (0.99–2.61)	0.055
ASA, n (%)				
I-II	38 (43.2%)	193 (73.1%)	Reference	
≥ III	50 (56.8%)	71 (26.9%)	3.58 (2.17–5.91)	**< 0.001**
BMI, kg/m^2, mean ± SD	23.5 ± 5.2	23.6 ± 5.1	1.00 (0.95–1.04)	0.851
Comorbidities, n (%)				
COPD	4 (4.5%)	3 (1.1%)	4.14 (0.91–18.89)	0.066
Asthma	4 (4.5%)	4 (1.5%)	3.10 (0.75–12.65)	0.116
OSA	1 (1.1%)	9 (3.4%)	0.33 (0.04–2.61)	0.291
Pleural effusion	8 (9.1%)	1 (0.4%)	26.30 (3.24–213.46)	**0.002**
Recent pneumonia	5 (5.7%)	1 (0.4%)	15.84 (1.83–137.54)	0.012
URI	2 (2.3%)	4 (1.5%)	1.51 (0.27–8.40)	0.637
Desaturation	8 (9.1%)	3 (1.1%)	8.70 (2.25–33.57)	**0.002**
Smoker	7 (8.0%)	8 (3.0%)	2.77 (0.97–7.86)	0.056
CHF	2 (2.3%)	4 (1.5%)	1.51 (0.27–8.40)	0.637
MI	6 (6.8%)	22 (8.3%)	0.8 (0.32–2.05)	0.650
CKD	14 (15.9%)	9 (3.4%)	5.36 (2.23–12.88)	**< 0.001**
ESRD	4 (4.5%)	6 (2.3%)	2.05 (0.56–7.43)	0.276
Dementia	4 (4.5%)	4 (1.5%)	3.1 (0.76–12.65)	0.116
GCS < 15	10 (11.4%)	1 (0.4%)	33.72 (4.25–267.5)	**0.001**
Neuromuscular disease	4 (4.5%)	1 (0.4%)	12.52 (1.38–113.6)	**0.025**
Cirrhosis	6 (6.8%)	4 (1.5%)	4.76 (1.31–17.27)	**0.018**
Ascites	2 (2.3%)	1 (0.4%)	6.12 (0.55–68.29)	0.141
SIRS/Sepsis	17 (19.3%)	16 (6.1%)	3.71 (1.79–7.72)	**< 0.001**
Septic shock	1 (1.1%)	2 (0.8%)	1.51 (0.13–16.8)	0.740
Recent blood transfusion	12 (13.6%)	15 (5.7%)	2.62 (1.18–5.84)	**0.018**
Laboratory values, n (%)				
Creatinine clearance (mL/min)				
≥ 60	47 (53.4%)	182 (68.9%)	Reference	
< 60	41 (46.6%)	70 (26.5%)	2.27 (1.37–3.74)	**0.001**
No test	0 (0.0%)	12 (4.5%)		

TABLE 1. Univariate analysis of preoperative risk factors associated with postoperative reintubation after planned extubation (n = 352). (Continue)

Variables	PRAP (n=88)	Control (n=264)	Crude OR (95% CI)	*P*-value
Hemoglobin (g/dL)				
≥ 12	42 (47.7%)	165 (62.5%)	Reference	
< 12	46 (52.3%)	96 (36.4%)	1.67 (1.05–2.66)	**0.031**
No test	0 (0.0%)	3 (1.1%)		
WBC count (cells/μL)				
< 11,000	63 (71.6%)	216 (81.8%)	Reference	
≥ 11,000	25 (28.4%)	45 (17.0%)	1.9 (1.08–3.35)	**0.025**
No test	0 (0.0%)	3 (1.1%)		
Serum albumin (g/dL)				
≥ 4	15 (17.0%)	28 (10.6%)	Reference	
< 4	51 (58.0%)	56 (21.2%)	1.7 (0.82–3.54)	0.156
No test	22 (25.0%)	180 (68.2%)		

P values < 0.05 indicate the statistical significance of the crude odds ratios.

Abbreviations: 95% CI, 95% Confidence Interval; ASA, ASA physical status; BMI, body mass index; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; ESRD, end-stage renal disease; GCS, Glasgow Coma Scale; MI, myocardial infarction; OR, odds ratio; OSA, obstructive sleep apnea; PRAP, postoperative reintubation after planned extubation; SIRS, systemic inflammatory response syndrome; URI, upper respiratory tract infection; WBC, white blood cell.

TABLE 2. Univariate analysis of operative and anesthetic risk factors associated with postoperative reintubation after planned extubation (n = 352).

Variables	PRAP (n=88)	Control (n=264)	Crude OR (95% CI)	*P*-value
Type of surgery, n (%)				
Head and Neck	12 (13.6%)	33 (12.5%)	Reference	
Airway	0 (0.0%)	22 (8.3%)	NA†	
Cardiothoracic	10 (11.4%)	6 (2.3%)	4.58 (1.37–15.35)	**0.014**
Vascular	2 (2.3%)	3 (1.1%)	1.83 (0.27–12.35)	0.533
Abdominal	12 (13.6%)	41 (15.5%)	0.8 (0.32–2.02)	0.645
Orthopedic	8 (9.1%)	36 (13.6%)	0.61 (0.22–1.68)	0.340
Neurologic	15 (17.0%)	11 (4.2%)	3.75 (1.35–10.41)	**0.011**
Urological	8 (9.1%)	18 (6.8%)	1.22 (0.42–3.54)	0.711
Obstetric and gynecologic	3 (3.4%)	25 (9.5%)	0.33 (0.08–1.3)	0.112
Others	18 (20.5%)	69 (26.1%)	0.72 (0.31–1.66)	0.438

TABLE 2. Univariate analysis of operative and anesthetic risk factors associated with postoperative reintubation after planned extubation (n = 352). (Continue)

Variables	PRAP (n=88)	Control (n=264)	Crude OR (95% CI)	*P*-value
Emergency surgery, n (%)	24 (27.3%)	46 (17.4%)	1.78 (0.05–1.01)	**0.047**
Duration of operation, n (%)				
< 1 hour	30 (34.1%)	81 (30.7%)	Reference	
1–3 hours	41 (46.6%)	133 (50.4%)	0.83 (0.48–1.44)	0.510
> 3 hours	17 (19.3%)	50 (18.9%)	0.92 (0.24–0.56)	0.808
Last NMBA, n (%)				
None/Succinylcholine	3 (3.4%)	12 (4.5%)	Reference	
Benzylisoquinoline (Atra/Cis)	71 (80.7%)	246 (93.2%)	1.15 (0.32–4.2)	0.828
Steroidal (Roc/Pan/Vec)	14 (15.9%)	6 (2.3%)	9.33 (1.91–45.58)	**0.006**
Last opioid, n (%)				
No opioid	1 (1.1%)	1 (0.4%)	Reference	
Fentanyl	65 (73.9%)	147 (55.7%)	0.44 (0.03–7.18)	0.566
Morphine	19 (21.6%)	114 (43.2%)	0.17 (0.01–2.78)	0.212
Meperidine	3 (3.4%)	2 (0.8%)	1.5 (0.06–40.63)	0.560
Time from last NMBA administration to reversal, n (%)				
No reversal	37 (42.0%)	114 (43.2%)	Reference	
< 45 mins	46 (52.3%)	130 (49.2%)	1.09 (0.66–1.80)	0.735
≥ 45 mins	5 (5.7%)	15 (5.7%)	1.03 (0.35–3.02)	0.961
Missing	0 (0.0%)	5 (1.9%)		
Time from last opioid administration to reversal, n (%)				
No reversal	18 (20.7%)	93 (35.4%)	Reference	
< 45 mins	64 (73.6%)	150 (57.0%)	2.20 (1.23–3.95)	**0.008**
≥ 45 mins	5 (5.7%)	15 (5.7%)	1.72 (0.56–5.34)	0.346
Missing	0 (0.0%)	5 (1.9%)		

P values < 0.05 indicate the statistical significance of the crude odds ratios.

† The odds ratio could not be calculated because no event occurred in the PRAP group.

Abbreviations: 95% CI, 95% Confidence Interval; Atra, atracurium; Cis, cisatracurium; NMBA, neuromuscular blocking agent; OR, odds ratio; Pan, pancuronium; PRAP, postoperative reintubation after planned extubation; Roc, rocuronium; Vec, vecuronium.

Patients with PRAP experienced significantly longer hospital and ICU stays, higher mortality rates, and an increased incidence of cardiac arrest. Additionally, PRAP was associated with a greater frequency of postoperative complications and blood transfusions. Detailed comparisons of postoperative outcomes between the PRAP and control groups are presented in Table 4.

TABLE 3. Final multivariable regression model showing risk factors associated with postoperative reintubation after planned extubation.

Variables	Adjusted OR (95% CI)	*P* value
ASA ≥ III	2.72 (1.58–4.66)	< 0.001
COPD	18.73 (1.60–219.22)	0.020
Creatinine clearance < 60 mL/min	3.38 (2.16–5.3)	< 0.001
Hemoglobin < 12 g/dL	1.76 (1.02–3.01)	0.041

P values < 0.05 indicate the statistical significance of the adjusted odds ratios.
Abbreviations: ASA, ASA physical status; COPD, chronic obstructive pulmonary disease; OR, odds ratio; PRAP, postoperative reintubation after planned extubation; WBC, white blood cell.

TABLE 4. Postoperative outcomes of the PRAP and the control groups (n = 352).

Postoperative outcomes	PRAP (n = 88)	Control (n = 264)	*P*-value
Length of hospital stay, day, median [IQR]	12.5 [7.5–22.0]	5.0 [3.0–10.0]	**< 0.001**
Length of ICU stay, day, median [IQR]	3.0 [0.0–6.0]	0.0 [0.0–0.0]	**< 0.001**
30-day mortality, n (%)	7 (8.0%)	4 (1.5%)	**0.007**
Cardiac arrest, n (%)	10 (11.4%)	3 (1.1%)	**< 0.001**
Blood transfusion, n (%)	38 (43.2%)	36 (13.6%)	**< 0.001**
Pulmonary complications, n (%)			
Pneumonia	12 (13.6%)	7 (2.7%)	**< 0.001**
On ventilator > 48 hour	38 (43.2%)	6 (2.3%)	**< 0.001**
Tracheostomy	5 (5.7%)	0 (0.0%)	**< 0.001**
Cardiac complications, n (%)			
Myocardial infarction	2 (2.3%)	2 (0.8%)	0.261
Heart failure	6 (6.8%)	0 (0.0%)	**< 0.001**
Renal complications, n (%)			
Acute renal failure	17 (19.3%)	10 (3.8%)	**< 0.001**
Urinary tract infection	10 (11.4%)	9 (3.4%)	**0.011**
Neurological complications, n (%)			
Cerebrovascular accident	4 (4.5%)	2 (0.8%)	**0.036**
Thromboembolic complications, n (%)			
Deep vein thrombosis	1 (1.1%)	1 (0.4%)	0.438
Pulmonary embolism	1 (1.1%)	1 (0.4%)	0.438
Infectious complications, n (%)			
Wound infection	1 (1.1%)	13 (4.9%)	0.204
SIRS/Sepsis	23 (26.1%)	20 (7.6%)	**< 0.001**
Septic shock	13 (14.8%)	7 (2.7%)	**< 0.001**

P values < 0.05 indicate the significance of the difference between the PRAP and control groups.
Abbreviations: ICU, intensive care unit; IQR, interquartile range; OR, odds ratio; PRAP, postoperative reintubation after planned extubation; SIRS, systemic inflammatory response syndrome. Postoperative outcomes were expressed as frequency (percentage) unless otherwise specified.

DISCUSSION

This study identified an incidence of PRAP of 0.06 % at Siriraj Hospital. Independent risk factors for PRAP included ASA physical status ≥ III, COPD, preoperative creatinine clearance < 60 mL/min, and hemoglobin < 12 g/dL. Furthermore, PRAP was significantly correlated with increased postoperative morbidity and mortality.

The observed PRAP incidence aligns with some previous studies[5,6,11]; however, it was lower than rates reported in Thailand two decades ago.[7,10] This reduction may reflect advancements in identifying patients requiring postoperative airway protection or positive pressure ventilation, leading to increased rates of postoperative intubation in high-risk cases. Changes in anesthetic practices, such as the greater adoption of short-acting anesthetic agents and neuromuscular blockade monitoring, likely contributed to this trend.[34,35] Improvements in surgical techniques may also be relevant; notably, none of the PRAP patients in this study underwent airway surgery, a procedure traditionally linked to higher risks of airway obstruction during extubation.[4]

Our findings differ from those of a previous study on patients undergoing elective intracranial surgery, which reported a higher incidence of PRAP.[8] This discrepancy may be explained by the high prevalence of consciousness disturbances in that patient population. Similarly, a prior study on orthotopic liver transplantation reported a significantly higher PRAP incidence than observed in our study.[9] This difference could be attributed to the inclusion of all reintubations occurring throughout the postoperative hospitalization period in the earlier study, thereby capturing PRAP cases related to later surgical and medical complications. Additionally, the higher PRAP incidence in liver transplant patients may reflect their greater burden of comorbidities and the increased surgical complexity associated with the procedure.

Our findings revealed that preoperative risk factors were the sole contributors to PRAP. ASA physical status ≥ III emerged as an independent risk factor, aligning with previous studies.[13] The ASA physical status classification system is a widely recognized tool for assessing preoperative comorbidities and has been shown to correlate with postoperative morbidity and mortality.[36] Despite its subjective nature and lack of surgical specificity, the ASA classification system remains valuable in predicting PRAP.[37]

COPD was also identified as a significant risk factor for PRAP. COPD is a chronic respiratory condition characterized by excessive mucus production and airway hyper-reactivity, which can result in postoperative airway obstruction, thus necessitating reintubation.[38] Notably, COPD is included under ASA physical status III.[17] Preoperative optimization strategies, such as bronchodilator and corticosteroid use and addressing modifiable factors like recent exacerbations, may reduce this risk.[39] Intraoperative management, including avoiding bronchospasm-inducing drugs and favoring bronchodilators, also mitigates risk.[38] Regional anesthesia can be considered for some procedures to minimize airway manipulation and the associated risks of endotracheal intubation.[40]

Preoperative low creatinine clearance and anemia were additional independent risk factors for PRAP, consistent with prior findings.[1,41] Impaired renal functions may alter drug metabolism, leading to the accumulation of renally excreted anesthetic agents, such as morphine and meperidine, thereby prolonging their effects.[42] Although a creatinine clearance < 60 mL/min is classified as early-stage CKD, it significantly increased PRAP risk in this study.[22] Anemia, by reducing oxygen delivery, can lead to hypoxemia and respiratory failure, necessitating reintubation and mechanical ventilation.[43] Given the high prevalence of preoperative anemia and its association with adverse outcomes,[44] identifying and addressing anemia preoperatively is essential.

Conversely, intraoperative and anesthetic factors were not significantly associated with PRAP in our multivariable regression model. Procedures such as airway, head and neck, and thoracic surgeries—previously identified as significant PRAP risk factors[6,7]—were not significant in this study. This discrepancy may reflect the high quality of surgical and anesthetic practices at our institution, delivered at our high-volume, tertiary care university hospital by experienced providers. Effective perioperative communication, multidisciplinary collaboration, and the adoption of a lower threshold for delaying extubation in high-risk patients may have contributed to this finding. Additionally, the use of steroidal NMBAs was not associated with PRAP, in contrast to findings from previous studies,[45,46] likely due to their infrequent use at our facility (5.7% of total study participants). Residual neuromuscular blockade is recognized as a contributor to postoperative reintubation.[47] However, neuromuscular monitoring was not routinely implemented at our institution; therefore, we lacked objective data on the degree of neuromuscular recovery before extubation. To address this limitation, we used the early reversal as a proxy indicator. This approach was based on prior literature suggesting that premature administration of reversal agents may reduce their predictability, potentially leading to residual blockade.[47] In our analysis, this timing variable was not significantly associated with PRAP. However, we acknowledge the limitation of using timing alone, as it

does not account for interindividual variability in drug metabolism and sensitivity, nor does it reflect whether adequate neuromuscular function was achieved prior to extubation.

The negative postoperative outcomes linked to PRAP, including higher mortality and increased postoperative complications, align with existing literature.[1-3] Endotracheal intubation increases the risk of hemodynamic instability such as hypertension and pulmonary complications such as hypoxia.[48] Additionally, reintubation presents a greater risk of difficult airway management and airway injury, as patients may develop airway edema due to prior intubation, intraoperative fluid resuscitation, or prolonged surgical positioning, such as the prone position.[49,50] These risks underscore the need for effective perioperative strategies to prevent PRAP.[1,2] Identifying high-risk patients along with addressing modifiable risk factors may help reduce PRAP incidence. In selected cases, delaying extubation to allow for hemodynamic stabilization or respiratory weaning may be a safer alternative.[4,51] However, the interpretation of these results should be approached with caution, as critical confounding factors—such as patient age, comorbidities, and surgical type—were not adjusted for in this analysis. Older age, a higher prevalence of comorbidities, and differences in surgical procedures may also contribute to the observed variations in postoperative outcomes between the PRAP and the control group.

Strengths and limitations

This study has notable strengths. First, it included patients undergoing diverse surgical procedures, enhancing the generalizability of the findings. Comprehensive data on preoperative, intraoperative, and anesthetic risk factors were collected, and time-matched control selection minimized potential biases arising from temporal changes in clinical practices. The use of multivariable regression analysis strengthened the reliability of the results. Additionally, the study evaluated postoperative outcomes associated with PRAP, providing a complete picture of the perioperative trajectory. Our findings confirm the significance of preoperative factors on the occurrence of PRAP, thus underscoring the importance of preoperative optimization, such as the optimal control of COPD and the correction of preoperative anemia. Future research is warranted to determine the effectiveness and magnitude of these strategies in reducing PRAP incidence and improving postoperative outcomes. Moreover, the identified risk factors can help perioperative healthcare professionals assess the necessity of delayed extubation in high-risk patients.

However, the study also has limitations. First, some preoperative laboratory test data were missing, particularly for younger and healthier patients, which may have introduced bias.[52] Second, the clinical indications for reintubation were not explored, limiting the understanding and the critical assessment of the decision-making process underlying reintubation. Thirdly, the absence of routine neuromuscular monitoring in our institution limited the ability to objectively assess residual neuromuscular blockade, which could be a contributing factor to PRAP. Lastly, the retrospective study design precludes causal inferences, and the findings should therefore be interpreted with caution.

CONCLUSION

The incidence of PRAP in this study was 0.06%. Independent risk factors for PRAP included ASA physical status ≥ III, COPD, creatinine clearance < 60 mL/min, and hemoglobin < 12 g/dL. PRAP was significantly associated with adverse postoperative outcomes, underscoring the need for preventive strategies and careful perioperative management.

Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Conflict of Interest

The authors declared no conflict of interest.

Registration Number of Clinical Trial

Not applicable.

Author Contributions

Conceptualization and methodology, P.N., M.D., A.S., and W.V.; Investigation, P.N. and M.D.; Formal analysis, M.D. and W.V.; Visualization and writing – original draft, M.D.; Writing – review and editing, W.V. and A.S.; Funding acquisition, P.N. and A.S.; Supervision, A.S. All authors have read and agreed to the final version of the manuscript.

Use of Artificial Intelligence

Not applicable.

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