Original Article

Independent predictors and clinical predictive score of postanesthetic reintubation after general anesthesia: A time-matched, case control study

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Abstract

Background and Aims: Postanesthetic reintubation is associated with increased morbidities and mortality; however, it can be reduced with defined predictors and using a score as a tool. This study aimed to identify independent predictors and develop a reliable predictive score.

Material and Methods: A retrospective, time-matched, case control study was conducted on patients who underwent general anesthesia between October 2017 and September 2021. Using stepwise multivariable logistic regression analysis, predictors were determined and the predictive score was developed and validated.

Results: Among 230 patients, 46 were in the reintubated group. Significant independent predictors included age >65 years (odds ratio [OR] 2.96 [95% confidence interval {CI} 1.23, 7.10]), the American Society of Anesthesiologists physical status III–IV (OR 6.60 [95%CI 2.50 17.41]), body mass index (BMI) ≥30 kg/m^2 (OR 4.91 [95% CI 1.55, 15.51]), and head and neck surgery (OR 4.35 [95% CI 1.46, 12.87]). The predictive model was then developed with an area under the receiver operating characteristic curve (AUC) of 0.84 (95% CI 0.78, 0.90). This score ranged from 0 to 29 and was classified into three subcategories for clinical practicability, in which the positive predictive values were 6.01 (95% CI 2.63, 11.50) for low risk, 18.64 (95% CI 9.69, 30.91) for moderate risk, and 71.05 (95% CI 54.09, 84.58) for high risk.

Conclusion: The independent predictors for postanesthetic reintubation according to this simplified risk-based scoring system designed to aid anesthesiologists before extubation were found to be advanced age, higher American Society of Anesthesiologists physical status, obesity, and head and neck surgery.

Keywords: Airway extubation, airway management, anesthesia recovery periods, intubation, predict model, prognostic

Introduction

Most patients are often uneventfully extubated after general anesthesia with endotracheal intubation; however, some patients require reintubation due to the occurrence of a life-threatening condition. Patients faced with postanesthetic reintubation have increased morbidities and mortality.[1–8] Higher mortality rates exceeding 30% to 40%[9–11] resulted from complications after reintubation.

The incidence of reintubation after general anesthesia was reported by previous studies to be 0.09% to 4%.[1–5,12–14] A literature review showed that there are various factors increasing the risk of reintubation after general anesthesia; patient factors include extreme age, higher American

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Society of Anesthesiologists physical status, preoperative pulmonary comorbidity, systemic inflammatory response syndrome (SIRS) or sepsis, congestive heart failure, and anemia,[1,2,4,12,15–19] whereas the anesthetic and surgical factors include emergency condition, extubating time during non-office hours, long operation duration, a residual effect of neuromuscular blocking or anesthetic agents, and high-risk surgery, for example, airway or head and neck surgery.[1,4,6,12,13,15,19,20] Currently, few studies exist with regards to predictive scores of postanesthetic reintubation.[15,18,20]

Many patients undergo surgery annually at an advanced tertiary referral center hospital. These patients have complex comorbid diseases and advanced surgical techniques are used, so increased postanesthetic complications occur. Postanesthetic reintubation is still a significant problem that leads to worse consequences. However, a simplified, user-friendly predictive score developed by data from this kind of hospital which can help anesthesiologists before extubation, still needs to be improved. Therefore, we designed this study to identify independent predictors and developed a scoring system to predict the risk of reintubation after general anesthesia.

Material and Methods

This is a retrospective, time-matched, case control study with a ratio of 1:4. After obtaining approval from our Institutional Review Board (IRB number: 089/2021, date of the approval was 19th Aug 2021) and Thai Clinical Trials Registry (TCTR 20220506001), we retrospectively identified reintubated and uneventfully extubated patients who underwent the operation under general anesthesia with endotracheal intubation between October 1, 2017 and September 30, 2021. The ratio of 1:4 means that after identifying one reintubated patient, we found four uneventfully extubated patients around that time from the anesthetic record database. The study flow diagram is shown in Figure 1.

Data were collected from electronic medical and anesthetic record forms, which included patient characteristics and significant comorbid diseases, preoperative laboratory results, type of surgery, extubation time, operative site, and duration of the last dose of opioid and muscle relaxant administered before extubation. The primary outcome was identifying preoperative independent predictors of postanesthetic reintubation. The secondary outcome was developing and validating a simplified clinical predictive score of postanesthetic reintubation from the statistical and clinically essential predictors.

The reintubated group consisted of patients who were reintubated at the operating theater or the postanesthetic care unit after planned extubation at the end of the operation. Exclusion criteria were patients who were aged less than 18 years, had previous intubation, were planned for retained endotracheal tube in the postoperative period, and had been unintentionally extubated after the operation.

The sample size was calculated using a formula without continuity correction by selecting the highest odds ratio (OR) proportion (American Society of Anesthesiologists physical status III–IV with an OR of 2.8) from Ittichaikulthol's[12] study, which has a similar population to our study. Based on a power

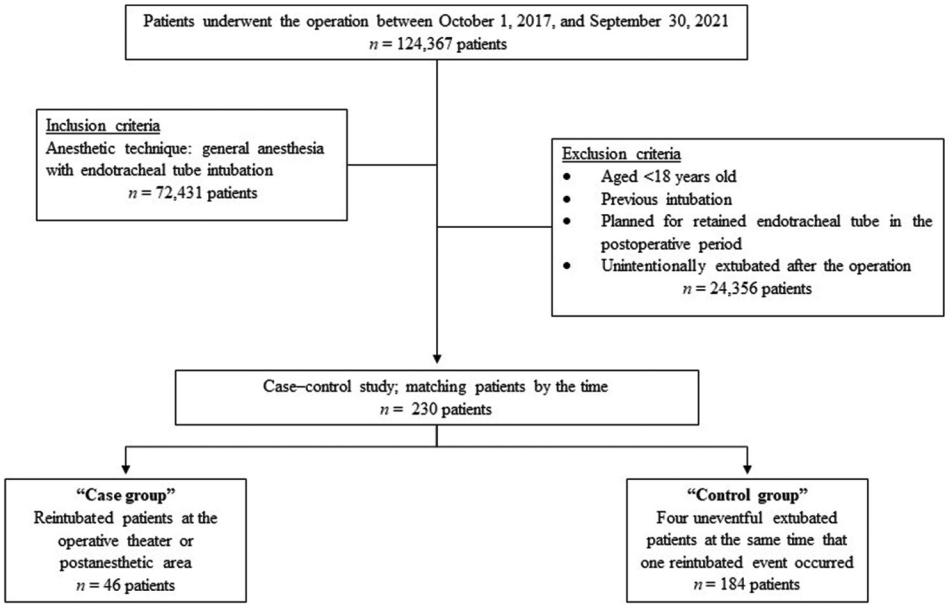

Figure 1: The study flow diagram

of 80% with an alpha error of 0.05, we chose the ratio of case to control, which was time matched, resulting in a ratio of 1:4 due to a rare incidence of postanesthetic reintubation and for increasing the power for prediction. The reintubated and non-reintubated groups numbered 46 and 184 subjects, respectively.

Statistical analysis

All data were statistically analyzed using STATA version 15. The potential predictors were selected based on our previous knowledge from the literature review and previous predictive models. Descriptive data were expressed using means and standard deviations (SDs) or medians and interquartile ranges (IQRs). Continuous potential predictors, for example, age, body mass index (BMI), serum hematocrit and potassium level, operative time, and duration of the last dose of any drugs used, were transformed into ordinal variables similar to the methods found in previous literature and reported as numbers and percentages. Fisher's exact tests were used for categorical variable analysis, with a *P* value <0.05 considered as statistically significant.

Stepwise multivariable logistic regression analysis was used to identify the independent predictors. Subsequently, some predictors were forced into a multivariable model because of their clinical importance. Backward elimination of nonsignificant predictors was then conducted in a stepwise manner. After model reduction, the final predictive score was developed by amplifying and rounding off the beta coefficient of those variables. The accuracy of this predictive score was evaluated in terms of calibration and discrimination. The Hosmer–Lemeshow goodness-of-fit statistics was used to measure the calibration score. A calibration plot comparing agreement between the probability of reintubation estimated via the predictive score and the actual reintubated patients was also presented. The power was tested and reported with an area under the receiver operating characteristic curve (AUC) for discriminative ability. Internal validation was performed by using the bootstrapping resampling procedure with 1000 replicates.

The total score was then classified into three risk categories (low, moderate, and high risk) for clinical practice applicability. Positive predictive value (PPV) was calculated to present the predictive performance separately for each risk category. The measurement of calibration and discrimination was also performed via a score-based multivariable logistic model.

Results

The data of 230 patients were collected, of which 46 and 184 patients were reintubated and non-reintubated, respectively.

The patient characteristics including gender, age, BMI, comorbid disease, preoperative laboratory results, the American Society of Anesthesiologists physical status, type of surgery, extubating time, operative site, operative time, and duration of the last dose of muscle relaxant and opioid used before extubation are presented in Table 1. The statistically significant differences between the two groups were age >65 years, BMI ≥30 kg/m^2, chronic pulmonary disease, congestive heart failure, the American Society of Anesthesiologists physical status III–IV, emergency surgery, extubating time, and operative site.

The significant independent predictors were age >65 years (OR: 2.96 [95% confidence interval {CI} 1.23,

Table 1: Patient characteristics of reintubated and non-reintubated groups

Variables	Reintubated group (*n*=46)	Non-reintubated group (*n*=184)	*P*
Sex (male)	27 (58.70)	80 (43.48)	0.071
Age >65 years	17 (36.96)	26 (14.13)	0.001
Median age, years (IQR)	61 (50–66)	52 (38–63)	
ASA PS: III–IV	38 (82.61)	67 (36.41)	<0.001
BMI ≥30 kg/m^2	12 (26.09)	10 (5.45)	<0.001
Comorbid disease			
Chronic pulmonary disease	6 (13.04)	7 (3.80)	0.026
Congestive heart failure	2 (4.35)	0	0.039
CNS disorder	2 (4.33)	6 (3.26)	0.662
Preoperative laboratory results			
Serum hematocrit <30%	8 (17.39)	20 (10.87)	0.218
Serum potassium <4 mmol/L	23 (50)	121 (65.76)	0.061
Emergency surgery	33 (71.74)	89 (48.37)	0.005
Extubating time during non-office hours	32 (69.57)	74 (40.22)	<0.001
Operative site			0.006
Head and neck	13 (28.26)	25 (13.59)	
Intracranial	2 (4.35)	0	
Intra-abdominal	21 (45.65)	110 (59.78)	
Extremities	10 (21.74)	49 (26.63)	
Operative time (h)			0.735
<1	12 (26.09)	54 (29.35)	
1–3	29 (63.04)	103 (55.98)	
>3	5 (13.91)	27 (14.67)	
Duration of the last dose of			
Muscle relaxant used >30 min	36 (78.26)	133 (72.28)	0.460
Opioid used >45 min	21 (45.65)	84 (45.65)	1.000

ASA PS=American Society of Anesthesiologists physical status, BMI=body mass index, CNS=central nervous system, IQR=interquartile range. Values are presented as number of patients (%) or medians and IQRs

7.10], $P = 0.015$), the American Society of Anesthesiologists physical status III–IV (OR: 6.60 [95% CI 2.50, 17.41], $P < 0.001$), BMI ≥ 30 kg/m^2 (OR: 4.91 [95% CI 1.55, 15.51], $P = 0.007$), and head and neck surgery (OR: 4.35 [95% CI 1.46, 12.87], $P = 0.008$) [Table 2]. Among them, the American Society of Anesthesiologists physical status III–IV appeared to have the highest OR.

Four statistically significant predictors in our study and three clinically significant predictors based on previous studies[3,12,13,15,19–21] were included in the calculations for the final predictive score, which was generated by using a beta coefficient as a weighted score. The total clinical predictive score ranged from 0 to 29, and the American Society of Anesthesiologists physical status III–IV was the highest scoring factor at 7.5. The AUC of this total predictive score was 0.84 (95% CI 1.19, 1.41) [Figure 2].

For clinical applicability, the score was further classified into three risk categories [Table 3], which still yielded good predictions as the AUC of this category was 0.82 (95% CI 0.75, 0.89). The low-risk group had scores ranging from 0 to 8.5 and a PPV of 6.01 (95% CI 2.63, 11.50) and the moderate risk group had scores ranging from 9 to 15 and a PPV of 18.64 (95% CI 9.69, 30.91), while the high-risk group had scores ranging from 15.5 to 29 and a PPV of 71.05 (95% CI 54.09, 84.58). The mean total score was significantly different between the two groups (6.14 ± 0.04 vs. 13.99 ± 0.79, $P < 0.001$).

Based on calibrations, these categories of data were plotted between the probability of reintubation and score distribution. For discriminative ability, the AUC of this categorized predictive score was 0.82 (95% CI 0.75, 0.89) [Figure 3]. A calibrated ability that was shown by the Hosmer–Lemeshow goodness-of-fit test was not significant ($P = 6.49$). From the plot, the predicted probability of reintubation increased as the score increased with an agreement between actual reintubated patients and predicted risks [Figure 4].

Internal validation was done by bootstrap resampling procedure at 1000 replicates to evaluate the model optimism. The apparent AUC was estimated at 0.85 (SD 0.029), the test AUC was estimated at 0.82 (SD 0.013), and the estimated optimism of AUC was 0.02 (SD 0.025).

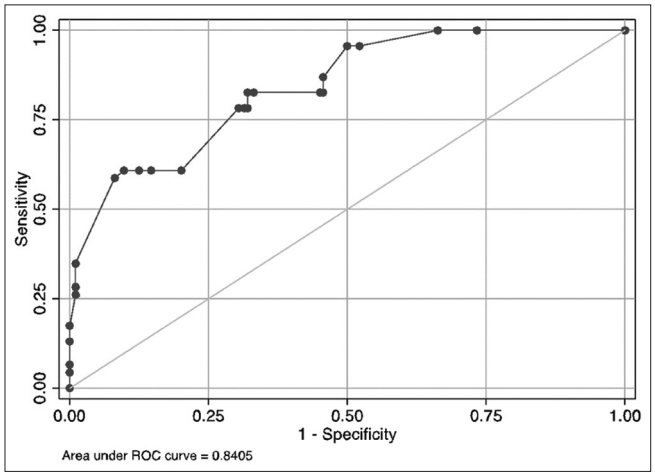

Figure 2: The AUC of the total predictive score was 0.84 (95% CI 0.78, 0.90). AUC = area under the receiver operating characteristic curve, CI = confidence interval

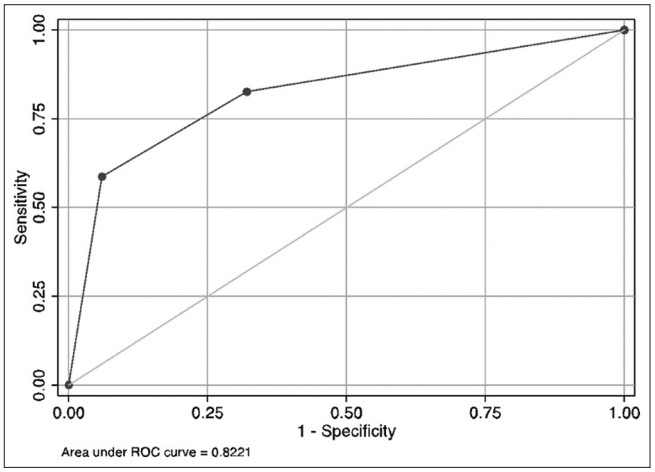

Figure 3: The AUC of the categorized predictive score was 0.82 (95% CI 0.75, 0.89). AUC = area under the receiver operating characteristic curve, CI = confidence interval

Table 2: Independent predictors and clinical predictive score of reintubation after general anesthesia, OR, 95% CI, *P* value, and beta coefficients

Variables	OR	95% CI	*P*	Beta coefficients	Score
Age >65 years	2.96	1.23, 7.10	0.015	1.084	4
ASA PS: III–IV	6.60	2.50, 17.41	<0.001	1.887	7.5
BMI ≥30 kg/m^2	4.91	1.55, 15.51	0.007	1.591	6
Head and neck surgery	4.35	1.46, 12.87	0.008	1.469	5.5
Chronic pulmonary comorbidities	1.93	0.52, 7.19	0.325	0.659	2.5
Emergency surgery	1.30	0.36, 4.62	0.683	0.263	1
Extubating time during non-office hours	2.02	0.56, 7.24	0.276	0.707	2.5

ASA PS=American Society of Anesthesiologists physical status, BMI=body mass index, CI=confidence interval, OR=odds ratio

Table 3: Distribution of risk for reintubation after general anesthesia across different levels of risk categories (low risk, moderate risk, and high risk), PPV, 95% CI, OR, and *P* value

Risk categories	Score	Reintubated group		Non-reintubated group		PPV	95% CI	OR	*P*
		n	%	*n*	%				
Low	0–8.5	8	17.4	125	67.9	6.01	2.63–11.50	1	
Moderate	9–15	11	23.9	48	26.1	18.64	9.69–30.91	3.58	0.01
High	15.5–29	27	58.7	11	6.0	71.05	54.09–84.58	38.35	<0.001
Mean±SE		6.14	±0.40	13.99	±0.79				<0.001

CI=confidence interval, OR=odds ratio, PPV=positive predictive value, SE=standard error

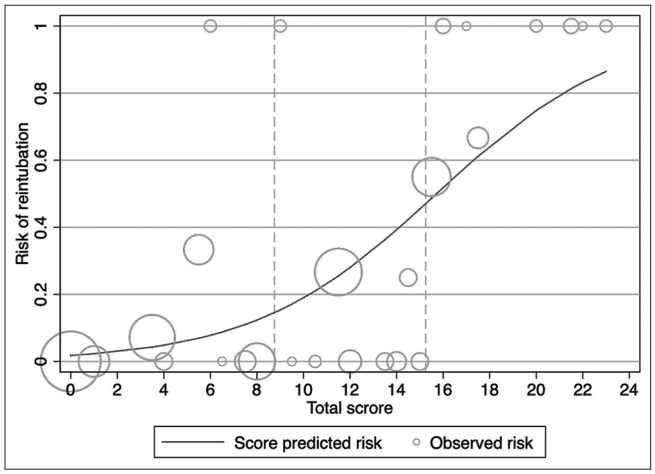

Figure 4: Predictive score calibration, actual reintubated patients (observed risk [circle]) versus score-predicted risk (solid line) of reintubation. Size of circle represents the frequency of reintubated patients in each score

Discussion

This study reports independent predictors of reintubation after general anesthesia, including age >65 years, the American Society of Anesthesiologists physical status III–IV, BMI ≥30 kg/m^2, and head and neck surgery, which are similar to those reported in previous studies.[2,12,13,16,19,20] We found that the American Society of Anesthesiologists classification was the most significant predictor, which had the highest OR of 6.6, corresponding to three previous studies.[2,12,13]

According to several studies, chronic pulmonary disease is a common clinical predictor of postanesthetic reintubation[1,3,13,17,19–21]; however, it was not included in our study. The rationale for this exclusion is mainly that patients with moderate to severe preoperative pulmonary disease were not extubated, which falls into the exclusion criteria for this study.

Emergency surgery and extubating time during non-office hours were the clinically important factors for the anesthesiologist to consider over retained endotracheal tubes because patients who were operated on under emergency conditions could have a worse preoperative status and suboptimal preoperative preparation. Moreover, in these situations, we often face the problem of limited resources available for crisis management, according to previous studies.[4,12,14]

When we generated the final clinical predictive score, four predictors were found to be statistically significant in our study: age >65 years, the American Society of Anesthesiologists physical status III–IV, BMI ≥30 kg/m^2, and head and neck surgery. In addition, three predictors were found to be clinically important: chronic pulmonary disease, emergency operation, and extubating time during non-office hours which was first used in the predictive model, all of which were selected to increase the prediction power in this scoring scheme.

Various predictive models have been reported before. For example, some models were used for predicting postoperative respiratory failure.[22–24] Johnson *et al*.[22] included the American Society of Anesthesiologists classification, emergency operations, more complex procedures (work relative value units), preoperative sepsis, and elevated creatinine in their model. Nevertheless, few models are used for predicting postanesthetic reintubation.[15,18,20]

Hua *et al*.[18] and Brueckmann *et al*.[15] chose the American Society of Anesthesiologists score, preoperative comorbidities such as sepsis or congestive heart failure or chronic pulmonary disease, operative time, emergency procedure, and high-risk services in their models, which were similar to our scoring scheme. On the other hand, Lin *et al*.[20] generated a more complex scoring system involving predictors such as conscious disturbance, cirrhosis or ascites, room air-oxygen saturation less than 95%, rocuronium used, and hypothermia to create their score.

However, some predictors have incomplete data in some situations, so their scores cannot be widely used. The ability to discriminate our clinical risk score for reintubation after general anesthesia was not different from the previous predictive models. This is shown by our AUC curve was 0.84 (95% CI 0.78, 0.90) compared to 0.87 (95%

CI 0.83,0.91) from Lin *et al*.'s[20] study, despite fewer predictors used.

Our model is different since we selected the predictors based on statistical and clinically significant predictors, which can be easily found in the preoperative period, except for the extubating time during non-office hours. However, extubating time also can know roughly before the operation start. Therefore, our score can help surgeons and anesthesiologists in stratification well before general anesthesia starts, giving enough time for proper management. Our predictive score is more simplified and, therefore, more suitable for situations involving many anesthetist personnel, including nurse-anesthetists, residents, and experienced anesthesiologists.

For clinical applicability, we categorized this predictive score into three risk-based subgroups. First, we could regularly extubate in the low-risk groups, for which the PPV was 6.01, compared to the high-risk groups, for which the PPV was 71.05, where we should delay extubation. Furthermore, extubation should be carefully considered in the moderate risk groups, for which the PPV was 18.64.

The limitations of this study are that it is a retrospective method; subsequently, some confounding predictors cannot be identified and some missing variables cannot be collected. Moreover, postanesthetic reintubation is a rare incidence; so, the number of subjects in our study was small ($n = 46$). However, our results showed enough power of discrimination. Further studies of prospective external validation should be carried out to confirm the robustness of these predictors and predictive scores.

The strength of this study is the use of multivariable statistical analysis that can adjust for potential confounding predictors. Furthermore, our study selected patients from various surgical procedures, so this score may extensively apply to general surgical patients with multiple procedures.

Conclusion

Our study suggests that the clinical predictors for postanesthetic reintubation are advanced age, higher American Society of Anesthesiologists score, obesity, and head and neck surgery. In addition, our study's simplified, suitable risk-based predictive score can be applied to patients in a wide range of surgical procedures and could guide anesthesiologists in clinical decision-making before extubation.

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Conflicts of interest
There are no conflicts of interest.

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