Original Article

Cardiac Variables as Main Predictors of Endotracheal Reintubation Rate after Cardiac Surgery

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Abstract

Background: Reintubation in patients after cardiac surgery is associated with undesirable consequences. The purpose of the present study was to identify variables that could predict reintubation necessity in this group of patients.

Methods: We performed a prospective study in 1000 consecutive adult patients undergoing cardiac surgery with cardiopulmonary bypass. The patients who required reintubation after extubation were compared with patients not requiring reintubation regarding demographic and preoperative clinical variables, including postoperative complications and in-hospital mortality.

Results: Postoperatively, 26 (2.6%) of the 1000 patients studied required reintubation due to respiratory, cardiac, or neurological reasons. Advanced age and mainly cardiac variables were determined as univariate intra- and postoperative predictors of reintubation (all p values < 0.05). Multiple logistic regression analysis revealed lower preoperative (p = 0.014; OR = 3.00, 95%CI: 1.25 - 7.21), and postoperative ejection fraction (p = 0.001; OR = 11.10, 95%CI: 3.88 - 31.79), valvular disease (p = 0.043; OR = 1.84, 95%CI: 1.05 - 3.96), arrhythmia (p = 0.006; OR = 3.84, 95%CI: 1.47 - 10.03), and postoperative intra-aortic balloon pump requirement (p = 0.019; OR = 4.20, 95%CI: 1.26 - 14.00) as the independent predictors of reintubation.

Conclusion: These findings reveal that cardiac variables are more common and significant predictors of reintubation after cardiac surgery in adult patients than are respiratory variables. The incidence of this complication, reintubation, is low, although it could result in significant postoperative morbidity and mortality.

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Introduction

In recent decades, interventional procedures in cardiac surgery have developed as widely used techniques of treating valvular dysfunctions and coronary artery diseases. To reduce postoperative complications and increase outcome

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in patients undergoing cardiac surgery, risk assessment is a vital component in the practice of cardiac surgery.[1, 2] Reintubation after cardiac surgery is unusual; however, it significantly increases postoperative morbidity and mortality risks.[3, 4] Reintubation prolongs the duration of mechanical ventilation and Intensive Care Unit (ICU) bed occupation and is associated with higher in-hospital mortality rates.[5-7] In addition, reintubated patients need more nursing care and financial resources. Unfortunately, few studies have been conducted to evaluate the rate of reintubation, factors related to reintubation, and patient outcome. Nonetheless, Engoren suggested respiratory variables as the main predicting factors of reintubation after cardiac surgery.[4]

Considering the original organ disease, i.e. cardiovascular diseases, in our patient population and the main procedure being performed, i.e. cardiac surgery, we hypothesized that cardiac variables could be significantly considered as the predictors of postoperative reintubation following cardiac surgery. The present study, therefore, aimed at determining the reintubation rate, factors related to postoperative cardiac surgery reintubation, and outcome of adult patients undergoing cardiac surgery.

Methods

This prospective observational study was conducted in a university hospital on adult patients undergoing cardiac surgical procedures using cardiopulmonary bypass (CPB) over a 5-month interval ending in March 2009. Data, including age, gender, New York Heart Association status (NYHA), ejection fraction (EF), smoking (regular cigarette smoking at least to two months before surgery), arterial partial pressure of oxygen (PaO_2), arterial partial pressure of carbon dioxide ($PaCO_2$), inotropic therapy, presence of an intra-aortic balloon pump (IABP), and comorbidity factors (diabetes mellitus: fasting blood surgery [FBS] > 126 mg/dL or history of diabetes requiring treatment, documented chronic obstructive pulmonary disease [COPD], and renal insufficiency [serum creatinine > 2 mg/dl]), were collected.

Inclusion criteria consisted of all adult patients who underwent (elective) cardiac surgery (coronary artery bypass grafting [CABG] and/or valvular surgery). We excluded patients who were intubated before surgery and those who underwent cardiopulmonary resuscitation or were in cardiogenic shock and also emergency operations. We also excluded patients who experienced severe complications in the cardiac catheterization laboratory and were urgently intubated and admitted to the operating room.

The definition of "reintubation" in this study was any repeated endotracheal intubation of extubated patients after cardiac surgery due to medical (cardiovascular, respiratory, neurological, etc.) causes and complications except the patients who were returned to the operating room for surgical re-exploration.

Benzodiazepine (Midazolam 0.05 to 0.1 mg/kg), opioids (Fentanyl 25 - 40 µg/kg or Sufentanil 2.5 - 4 µg/kg), and muscle relaxants (Cisatracurium 0.15 mg/kg/IV bolus) for induction and Thiopental 1 - 2 mg/kg before tracheal intubation were administered. For maintenance, Midazolam, Fentanyl or Sufentanil, Atracurium or Pancuronium, and Isoflurane up to 1% were administered.

All the operations were performed using CPB at mild to moderate hypothermia (28 to 32 ˚C). Myocardial protection was accomplished with intermittent antegrade or combined antegrade and retrograde saline or blood cardioplegia. The patients were extubated according to the following extubation criteria: respiratory rate = 10 - 28 / min; negative inspiratory force > 20 cm H_2O; tidal volume > 5 ml/kg body weight; PaO_2 > 60 mm Hg with fraction of inspired oxygen (FIO_2) < 0.4; $PaCO_2$ < 50 mm Hg; hemodynamic stability; mediastinal and chest tubes drainage < 100 ml/h; oropharyngeal temperature > 36.5 ˚C; and acceptable chest radiographies.[3] Postoperative pain was controlled using intravenous Morphine or Fentanyl and Sodium Diclofenac suppository. Midazolam and Haloperidol were also used for controlling sedation and agitation, respectively. During ICU stay, respiratory, nephrology, and neurological complications were checked daily by cardiac anesthesiologists.

Duration of mechanical ventilation was defined as the hours with mechanical ventilation during ICU stay. Daily postoperative chest radiographies were obtained for evidence of pulmonary complications such as plural effusion, atelectasis, and pneumothorax. Cardiovascular status, defined as cardiac rhythm and need to inotropic drugs or IABP, was checked every day. Significant arrhythmias were described to be those causing hemodynamic instability and requiring treatment. The necessity for inotropic medication administration was defined as a moderate to high doses of one of the inotropic drugs required for hemodynamic stability for more than one hour. Postoperative EF was determined using transthoracic echocardiography (TTE) and compared with preoperative values. Bleeding was defined as ≥ 200 mL/h or > 1000 mL in twenty-four hours. Tamponade was delineated by clinical examination and TTE and then confirmed after re-exploration. Postoperative renal insufficiency was considered as creatinine concentration > 2 mg/dL or increase in preoperative values > 1 mg/dL. Stroke was described as a neurological abnormality confirmed by a neurologist. Infection was confirmed by positive blood, sputum, urine, plural, or mediastinal fluid cultures and incision discharge. The length of ICU stay and in-hospital mortality were additionally considered.

The patients were evaluated regarding preoperative, operative, and postoperative characteristics to determine which would mostly predict reintubation necessity. All preoperative, operative, and outcome data were recorded postoperatively and analyzed using SPSS statistical package

version 15.0 (SPSS Inc. Chicago, IL, USA). In the re-intubated patients (n = 26), the Kolmogorov-Smirnov test was applied to check for normal distribution in the continuous variables and only "ventilation time" and "ICU stay time" did not fit normal distribution and were, therefore, removed from the univariate analysis. To compare the continuous variables between the two study groups, the independent samples t-test; and to compare the categorical variables; the Chi-square test or the Fisher exact test were used. The reintubated group was compared with the non-reintubated group (n = 946) using univariate and multivariate analyses to identify predictors for reintubation. Binary logistic regression with a stepwise forward selection procedure was employed to develop a model predictive of reintubation after cardiac surgery. Variables that were univariately significant at the 0.10 level were considered for inclusion in the model. A p value < 0.05 was required for the variable to enter and stay in the model. Improvement of model was judged by the Akaike information criterion (AIC). A significant level was considered as a p value ≤ 0.05. The present study protocol was approved by the institutional review board.

Results

Of the 1000 studied patients, 22 patients were not extubated and none of them survived. These 22 patients were excluded from the final analysis. From the 978 patients, who underwent extubation, 32 patients experienced reintubation

due to emergent surgical re-exploration or postoperative complications such as respiratory, cardiac, or neurological complications (Table 1). Of the 32 reintubated patients, 6 patients were emergently returned to the operating room for surgical re-exploration and reintubated after inducing general anesthesia; these patients were excluded from the statistical analysis as well. Finally 972 patients, who experienced extubation after cardiac surgery, were entered into the statistical analysis: 26 patients who experienced reintubation after extubation in the intensive care unit (ICU) and 946 patients who were extubated successfully.

Of the 972 patients analyzed, 624 (67%) were male and 348 (33%) were female. The mean age of the patients was 57 ± 12.50 years. Tables 2, 3, and 4 present the relationships between all the perioperative variables and reintubation in the reintubated group (n = 26) and the non-reintubated group (n = 946) using univariate analysis.

Our results revealed that the reintubated patients were significantly older and had lower preoperative EF and PaO_2 than did the control group (Table 2). In addition, the reintubated patients had significantly longer operating and CPB times, more valvular diseases, and more emergent surgical operations (Table 3). In the postoperative period (Table 4), the reintubated patients also developed arrhythmias, plural effusion, bleeding, neurological complications, renal failure, and infection and had longer mechanical ventilation more significantly. A postoperative EF lower than the preoperative value was more significant in the reintubated patients than

Table 1. Reintubation reasons amongst all reintubated patients (n=32)

Respiratory (n=9)	Cardiac (n=16)	Neurological (n=1)	Emergent reoperation (n=6)
Secretions	Cardiogenic pulmonary edema	Stroke and seizure	Surgical bleeding
Respiratory failure	Cardiac failure		CVC site bleeding
Bronchospasm	Cardiac arrest		
Hypoxemia	Arrhythmia		

CVC, Central venous catheterization

Table 2. Univariate analysis of the patients' preoperative characteristics[*]

Variables	Reintubated group (n=26)	Non-reintubated group (n=946)	P value
Age (y)	60.2±12.3	54.4±13.3	0.017
Sex (M/F)	18 (69) / 8 (31)	605 (64) / 341 (36)	0.580
NYHA functional Class (I-II/III-IV)	17 (65) / 9 (35)	747 (79) / 199 (21)	0.430
EF < 35% / EF ≥ 35%	7 (27) / 19 (73)	95 (10) / 851 (90)	0.002
Inotropic therapy	0	19 (2)	1.000
IABP presence	0	10 (1.1)	1.000
Diabetes	6 (23)	200 (21.1)	0.812
Renal insufficiency	2 (7.6)	30 (3.2)	0.220
COPD	2 (7.6)	26 (2.7)	0.170
Smoking	7 (27)	225 (23.8)	0.816
PaO_2 (mm Hg)	68.8±11.2	74.2±10.7	0.017
$PaCO_2$ (mm Hg)	38.9±12.4	38.1±5.9	0.595

[*]Data are presented as mean±SD or n (%)
NYHA, New York Heart Association; EF, Ejection fraction; IABP, Intra-aortic balloon pump; COPD, Chronic obstructive pulmonary disease; PaO_2, Arterial partial pressure of oxygen; $PaCO_2$, Arterial partial pressure of carbon dioxide

Table 3. Univariate analysis of the patients' operative characteristics*

Variables	Reintubated group (n=26)	Non- reintubated group (n=946)	P value
Type of operation			0.038
CABG	15 (56.7)	696 (73.6)	
Valvular	9 (35.6)	213 (22.5)	
CABG + Valvular	2 (7.7)	37 (3.9)	
Emergency case	4 (15.3)	40 (4.2%)	0.026
Reoperation	4 (15.3)	85 (9%)	0.292
Operation time (min)	289±84	229±57	< 0.001
Pump time (min)	110±47	90±33	0.044

*Data are presented as mean±SD or n (%)
CABG, Coronary artery bypass grafting

Table 4. Univariate analysis of the patients' postoperative characteristics and complications*

Variables	Reintubated group (n=26)	Non-reintubated group (n=946)	P value
Fluid balance (-/ 0 /+)	0%/76.9%/23.1%	5.8%/82.5%/11.7%	0.112
Ventilation time (hr)	14 (7.5-40.5)**	7.25 (5.25-10.5)	0.012
Plural effusion	26.9%	12.5%	0.027
Atelectasis	11.5%	7.3%	0.433
Pneumothorax	7.7%	2%	0.106
Arrhythmia	46.1%	7.9%	< 0.001
Inotropic drugs usage	73%	13.8%	< 0.001
IABP usage	30.7%	1.3%	< 0.001
Postoperative EF change (≥ preop. EF/< preop. EF)	34.6%/65.4%	93.5%/6.5%	0.001
Bleeding	30.7%	13.6%	0.013
Tamponade	3.8%	0.8%	0.217
Renal insufficiency	19.2%	0.5%	< 0.001
Neurological event	26.9%	2.6%	< 0.001
Infection	26.9%	0.4%	< 0.001
In-hospital mortality	42.3%	0%	< 0.001
ICU stay (day)	9.8±8.8	3.4±1.4	0.002

*Data are presented as per cent, mean±SD or median (interquartile range)
**Total ventilation time was considered.
IABP, Intra-aortic balloon pump; ≥ preop EF, Post operative ejection fraction equal to or more than preoperative ejection fraction; < preop EF, Post operative ejection fraction less than preoperative ejection fraction; ICU, Intensive care unit

in the control group. The reintubated patients also required more inotropic drugs and IABP in the postoperative period and had longer ICU stay. The mortality rate in this group of patients was 42.3% (11 of 26), while no patients in the control group died during hospital stay.

The limited number of the reintubated patients in our study (n = 26) forced us to include the limited variables in the regression model each time separately; as a result, the patients were entered in the model with respect to their preoperative, operative, and postoperative characteristics separately. The postoperative variables in turn were divided into "respiratory", "cardiovascular", and "other" for inclusion in the regression model separately. In the preoperative variables, age and EF had a p value < 0.10 and were entered in the model and then only EF < 35% was a predictor of reintubation in the ICU (p = 0.014, OR = 3.00, 95%CI: 1.25 - 7.21). Amongst the operative variables, valvular heart

surgery was the predictor of reintubation (p = 0.043, OR = 1.84, 95%CI: 1.05 - 3.96). Operation time > 180 minutes showed a clinically important but non-significant p value in predicting reintubation (p value = 0.090; OR = 3.48, 95%CI: 0.81 - 14.87). In the postoperative respiratory variables, only pleural effusion was a predictor of reintubation (p value = 0.024, OR = 2.93, 95%CI: 1.15 - 7.45). Of the postoperative cardiac variables, inotropic drug usage did not qualify in the stepwise forward selection (p value = 0.079), while arrhythmia (p = 0.006, OR = 3.84, 95%CI: 1.47 - 10.03), postoperative EF reduction (p = 0.001, OR = 11.10, 95%CI: 3.88 - 31.79), and IABP use (p = 0.019, OR = 4.20, 95%CI: 1.26 - 14.00) were the predictors of reintubation. In the other postoperative variables, bleeding did not qualify in the stepwise forward selection (p value = 0.208), but neurological complications (p = 0.049, OR = 2.93, 95%CI: 1.01 - 15.63), nephrological complications (p value = 0.038, OR = 7.47,

95%CI: 1.12 - 50.10), and infectious complications (p value = 0.001, OR = 19.10, 95%CI: 3.46 - 27.71) were the predictors of reintubation in the ICU.

Discussion

In this prospective observational study, we compared reintubated patients with those not reintubated after cardiac surgery. The reintubation rate after cardiac surgery was 2.6%, which was similar to that reported by numerous earlier reports.[4, 8] The incidence of reintubation in previous studies[7, 9-11] on patients undergoing cardiac surgery was from 1.1% to 6.6%. In fact, the improvement in patients' medical care within recent years has decreased the rate of post-cardiac surgery reintubation. In a study, Habib et al.,[9] found a 2.8 and 3.5% reintubation rate in two groups of patients with early and late extubation time after cardiac surgery, respectively. Also, Engoren et al.,[4] in another study conducted on adult patients reported a 4.2% reintubation rate after cardiac surgery. Moreover, they noted that the reintubation rate was higher in patients with co-morbid conditions related to cardiac surgery. Redmond[12] reported that a history of stroke increased the reintubation rate to 9.9%

Cohen et al.,[13] concluded that the presence of COPD in patients increased the reintubation rate up to 13.5% after cardiac surgery. Lauruschkat et al.,[10] found that the incidence rates of reintubation amongst diabetic and non-diabetic patients were 4.5% and 1.8%, respectively. Using univariate analysis, we found that the patients with advanced age and lower preoperative EF and PaO_2 had higher reintubation rates. However, after controlling the effect of age, the PaO_2 value was not a strong marker for predicting reintubation. Whereas some previous studies reported COPD as a risk factor for reintubation,[4, 13] we found no strong correlation between COPD and smoking and reintubation. Similarly, Spivack[14] and Branca[15] found that COPD was not a predictor of respiratory complications, including postoperative respiratory ventilation time. In the present study, in comparison with the control group, the reintubated patients had a high incidence rate of preoperative renal failure but there was no statistically significant difference between the two groups. In contrast, several previous studies have reported a significant correlation between preoperative renal failure and reintubation rate or duration of postoperative mechanical ventilation.[4, 16]

In our univariate analysis, valvular surgery or CABG plus valvular surgery, urgency of surgery, longer operation time, and CPB were the risk factors for reintubation. Similarly, in some previous reports, these variables were associated with higher reintubation rates and longer mechanical ventilation times.[4, 15] All these factors are probably dependent on one another and reflect patients with poorer conditions and more complicated operations.

In the present study, arrhythmia, plural effusion, inotropic drugs and IABP requirement, lower postoperative EF in comparison with preoperative values, and longer mechanical ventilation significantly correlated with reintubation rates and complicated cardiac surgery.

In our study, positive fluid balance had no correlation with the reintubation rate. However, in numerous studies fluid balance has been reported to be associated with prolonged mechanical ventilation and reintubation rate.[4, 16] This discrepancy may reflect the different description of positive fluid balance in our study (We proposed positive balance > 1000 mL within the first twenty-four hours as positive fluid balance). We found that the pre- and postoperative EF, surgery on heart valve, arrhythmia, and postoperative requirement of IABP and inotropic drugs were the predictors of reintubation. Nevertheless in a previous study by Engoren,[4] three predictors related to the reintubation rate were COPD, respiratory rate, and lower vital capacity. Surprisingly, preoperative PaO_2 and COPD did not predict the need for reintubation. The fact that there was a limited number of COPD patients in our study (despite the presence of a large number of smoking patients in our study population in contrast to previous reports) may be due to the exclusion of severe COPD cases by cardiologists during preoperative medical examinations. Fuster et al.[17] showed that the severity of COPD but not COPD itself could be an important factor in the prognosis of coronary artery bypass grafting. Nineteen (73%) patients were reintubated within a twenty-four hour period after extubation; this appears to be in consequence of the patients' poor primary general condition. These findings are in line with the higher percentage of patients with valvular disease in the present study. Moreover, neurological complications, renal failure, infection, and longer ICU stay were associated with the reintubation rate in our study. Similar to our study, several investigations[16, 18] have defined reintubation as a significant factor increasing postoperative complications and prolonged ICU and hospital stay. In our survey, 11 (42.3%) of the reintubated patients died (10 cases due to cardiac and 1 patient due to respiratory complications), which was much higher than the figure in an earlier report (9.8%).[4] In this respect, Murthy et al.[19] showed that hemodynamic status was the main factor for predicting respiratory complications. Also, Wahl[2] described that patients with respiratory failure caused by organ dysfunction (e.g. cardiac pump failure or stroke) were more prone to reintubation than were patients with initial respiratory failure (e.g. pneumonia and COPD deterioration). In another study, Spivack et al.[14] suggested that complications of the cardiovascular system and other organs such as the brain were important restricting factors for postoperative recovery of the respiratory system.

The limitation of the present study was its relatively small sample size inasmuch as there were only 26 cases of reintubation in our 1000 study patients. The fact that this was a uni-center study and not a multi-center study also

diminishes the generalizability of our results.

Conclusion

In summary, the present study confirms that reintubation after cardiac surgery is a marker for morbid postoperative period. We found that reintubated patients were more prone to having complications, longer ICU stay, and higher in-hospital mortality rates. We also demonstrated that cardiac variables have a significant role in reintubation and mortality rate prediction.

Consequently, patients undergoing cardiac surgery with reduced cardiac reserve and hemodynamic instability are at risk of reintubation. Particular attention should be paid in these patients to prevent postoperative reintubation.

Acknowledgements

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