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ORIGINAL ARTICLE

Risk factors for developing respiratory complications after coronary artery bypass surgery

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ABSTRACT

Aim To identify independent risk factors associated with postoperative respiratory complications (PRCs) in patients undergoing coronary artery bypass surgery (CABG).

Methods A retrospective cohort study was conducted on 98 patients (82 males, 16 females) who underwent CABG at the Cardiovascular Surgery Clinic, University Hospital Tuzla. The incidence of PRC and potential risk factors were analysed. Univariate analysis was performed to assess associations, followed by multivariable logistic regression to adjust for confounding factors. Independent risk factors were identified, including diabetes mellitus, smoking, hypertension, gender, and preoperative oxygen saturation <94%.

Results PRCs were observed in 48 (48.97%) patients. Preoperative factors significantly associated with PRCs included diabetes mellitus, smoking, hypertension, and low preoperative oxygen saturation. Intraoperative and postoperative factors, such as prolonged surgery duration (>180 min), mechanical ventilation >120 min, and blood transfusion exceeding 500 ml/24 h, were also identified as risk factors. Multivariable logistic regression confirmed that prolonged surgery duration, extended respiratory support, and transfusions >500 ml/24 h were independent predictors of PRCs.

Conclusion This study highlights the importance of perioperative risk stratification in preventing PRCs . Reducing prolonged mechanical ventilation and minimizing unnecessary transfusions may improve postoperative outcomes. Further studies with larger cohorts are needed to refine risk prediction models and optimize perioperative management strategies.

Keywords: anaesthesia, blood transfusions, cardiac surgery, prevention

INTRODUCTION

Perioperative risk factors effect of the patients recovery and continue to occur in the early postoperative period. Known preoperative comorbidities (age, smoking, obesity, diabetes mellitus and low ejection fraction <40%) still have an effect on postoperative recovery after bypass surgery (1).

The development of cardiac surgery in the last decade, with the introduction of new operative techniques and treatment methods, has contributed to the shift in the indication parameters for surgery. There are still numerous debates surrounding invasive and non-invasive treatments for coronary disease and their benefits in relation to treatment outcomes (2). General anaesthesia, with the administration of drugs, affects respiratory function, resulting in a decrease in functional residual capacity (3). Another important factor affecting respiratory function is cardiopulmonary bypass (CPB) and the interruption of ventilation during CPR (4).

Lung injury results from the activation of inflammatory factors during cardiopulmonary bypass procedures, which can be mitigated by the use of corticosteroids (5).

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The activation of neutrophils and platelets obstructs the pulmonary microcirculation, causing a disturbance in pulmonary circulation after reperfusion. The activation of neutrophils and platelets obstructs the pulmonary microcirculation, causing a disturbance in pulmonary circulation after reperfusion (6). In some cases, non-immunogenic anaphylaxis related to heparin-protamine administration can cause bronchospasm and pulmonary oedema. Studies report the prevalence of these reactions varying in the range 0.06-10.7% (7).

As a consequence of ischemia–reperfusion injury during cardiopulmonary bypass, various pulmonary complications may occur, including pneumonia, atelectasis, pulmonary embolism, and prolonged mechanical ventilation (8). Perioperative risk factors include: anaesthesia, operative incision, cardioplegia, duration of cardiopulmonary bypass (CPB), the amount of transfused blood, and ventilator support (9).

The increase in the number of cardiovascular diseases has led to a rise in the number of cardiac surgery procedures. This necessitates continuous progress and revisions to reduce mortality, despite the increased number of operations (10).

Ryz et al. analysed intraoperative predictors to identify high-risk patients and improve postoperative pulmonary outcomes (11). The study aimed to optimize postoperative pulmonary results through the implementation of targeted lung-protective strategies, such as low tidal volume ventilation, alveolar re-

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cruitment manoeuvres, and controlled FiO2 exposure during surgery (12).

We conducted this research to address the lack of structured analysis of intraoperative predictors of respiratory complications in cardiac surgery patients at our centre. Despite a number of different surgeries, a standardized model for intraoperative risk assessment is not routinely implemented. Through this study we aim to identify modifiable factors that can improve postoperative outcomes, enhance patient's safety, and align our protocols with best practices worldwide.

The aim of this study was to determine the risk factors, which are often modifiable and directly related to the quality of perioperative care.

PATIENTS AND METODS

Patients and study design

This prospective study included 98 patients who underwent coronary artery bypass surgery (CABG) at the Cardiovascular Surgery Clinic, University Hospital Tuzla between June 2021 and December 2022. Data were collected using the hospital's electronic system (BIS), including gender, smoking status, age, diabetes mellitus, hypertension, and oxygen saturation level. Smoking history was defined as current or previous daily smoking. Hypertension was defined as blood pressure >140/90 mmHg or the use of antihypertensive medication. Diabetes mellitus was diagnosed as fasting glucose >7 mmol/L or prior use of antidiabetic medication. Oxygen saturation <94% was considered low.

This study was approved by the Ethics Committee of the University Clinical Centre Tuzla.

Methods

All patients were sedated according to the standard anaesthesia protocol for cardiac surgery using midazolam (2.5–5.0 mg). A central venous catheter (CVC) and an arterial line for invasive monitoring were placed in all patients. For anaesthesia induction, the following medications were administered: Midazolam (0.1–0.3 mg/kg); Fentanyl (20–50 mcg/kg); Pancuronium (0.04–0.08 mg/kg). During the procedure, anaesthesia was maintained with: Midazolam (3–4 mg/kg/h); Pancuronium (2 mg/h); Fentanyl (120–150 mcg/h); Sevoflurane (MAC 1–2 vol%). Anaesthesia was continuously administered until the patient left the operating room. All surgical procedures were performed under general anaesthesia with the use of a cardiopulmonary bypass (CPB) machine. The following intraoperative variables were recorded: cardiopulmonary bypass (CPB) time, total operation time, aortic cross-clamp (CC) time.

After surgery the patients were transferred to the Cardiovascular Intensive Care Unit (CICU). International ERS/ESICM/ESCMID/ALAT guidelines (13) were followed to define pneumonia, characterized by new and/or progressive pulmonary infiltrates on chest radiographs, presence of at least two of the following criteria: fever >38°C, leukocytosis $>12\times10^9$/L, purulent respiratory secretions, and microbiological evidence of infection (endotracheal aspiration).

Other respiratory complications including atelectasis, pleural effusion, pneumothorax (PNTX), and pulmonary oedema were detected using chest radiography. The type and number of respiratory complications were recorded and analysed in relation to intraoperative and postoperative risk factors. Postoperative variables included: duration of mechanical ventilation, number of red blood cell transfusion units, need for inotropic support, ICU length of stay. Prolonged ventilation time was defined as a ventilation period exceeding 24 hours.

Statistical analysis

Descriptive statistics were reported as mean ±standard deviation (SD). Categorical variables were presented as percentages. Independent samples t-test was used for analysing continuous variables. Fisher's exact test and χ^2 test were used for analysing categorical variables. Univariate and multivariable logistic regression was performed to determine risk factors for postoperative respiratory complications. In univariate analysis, continuous variables were compared using the t-test, while categorical variables were analysed using the χ^2 test. A p-value less then 0.05 was considered statistically significant. In multivariable analysis, adjusted odds ratio (AOR) with 95% confidence intervals (CI) was calculated to identify independent predictors of postoperative respiratory complications. Odds ratios (OR) from univariate analysis were used to assess unadjusted associations.

RESULTS

Among 98 patients there were 82 males (83.67%) and 16 females (16.32%). Among 48 patients who developed PRC, 33 (33.34%) were male, and 15 (15.30%) were female (p=0.001). Smoking was presented in 52 (53.06%) patients; 40 (49.00%) smokers developed PRCs compared to eight (8.16%) non-smokers (p=0.001). Diabetes mellitus was recorded in 50 (51.02%, with a higher prevalence among patients with PRCs comparing to the patients without PRCs (34.69% vs. 14.29%; p=0.001).

Hypertension was significantly associated with postoperative respiratory complications (PRC), with 41.83% of hypertensive patients developing PRCs compared to only 7.14% of non-hypertensive patients (p=0.002). Similarly, oxygen saturation below 94% was more frequently observed in patients with PCRs (p=0.012). In contrast, age showed no significant association with PCRs, as the distribution between patients younger and older than 65 years was similar (p=0.919) (Table 1).

Table 1. Demographic preoperative characteristic of patients with and without postoperative respiratory complications (PRCs)

Variable		No (%) of patients	
		Total	With PCR
Gender	Male	82 (83.67)	33 (33.34)
	Female	16 (16.32)	15 (15.30)
Smoking	YES	52(53.06)	40(49.00)
	NO	46 (46.93)	8 (8.16)
Age	<65 yr	51 (52.04)	25 (25.51)
	>65 yr	47 (47.95)	23 (23.46)
Diabetes mellitus	YES	50 (51.02)	34 (34.69)
	NO	48 (48.97)	14 (14.29)
Hypertension	YES	81(82.65)	41 (41.83)
	NO	17 (17.34)	7 (7.14)
Oxygen saturation	<94%	7 (7.14)	5 (5.10)
	>94%	92 (93.87)	43 (43.87)

The most common respiratory complication was pneumonia, affecting 25 (25.51%) patients. Other complications included: pleural effusion in 15 (15.30%) patients, atelectasis in seven (7.14%), respiratory insufficiency in four (4.08%), pulmonary oedema in three (3.06%), pneumothorax (PNTX) in one (0.98%) patient. Some patients developed multiple complications (Table 2).

Table 2. Prevalence of early postoperative respiratory complications*

Complications	No (%) of patients (N=78)
Pneumonia	48 (48.97)
Pleural effusion	15 (15.30)
Atelectasis	7 (7.14)
Respiratory Insufficiency	4 (4.8)
Pulmonary oedema	3 (3.06)
Pneumothorax	1(0.98)

*Patients may have multiple complications, and percentages reflect the total number of complications observed

Patients with a prolonged ICU stay (>48h) had a higher prevalence of PRCs, 25 (25.51%), compared to those with a shorter stay, 23 (23.46%), without statistical significance (p=0.083). A longer duration of surgery (>180 min) was significantly associated with PRCs, 34 (34.69%) patients developed complications compared to 14 (14.28%) in the group with shorter surgical times (p=0.041). Cardiopulmonary bypass (CPB) time and cross-clamp (CC) time did not show statistically significant associations with PRCs (p=0.280 and p=0.288, respectively) (Table 3).

Table 3.Intraoperative and postoperative factors associated with postoperative respiratory complications (PRCs)

Variable	No (%) of patients		OR	p
	Without PRC	With PRC		
ICU length of stay				<0.05
>48h	48 (48.97	25(25.51)	1.18	
<48h	50 (51.02)	23(23.46)		
Duration of surgery				<0.05
>180 min	53(54.08)	34(34.69)	2.18	
<180 min	45 (45.91)	14(14.28)		
CPB time				>0.05
>120 min	44 (44.89)	25(25.33)	0.35	
<120 min	54 (55.10)	23(23.66)		
cCC time				>0.05
>30 min	43 (43.87)	22(22.44)	0.34	
<30 min	55 (56.12)	26(26.53)		
dMV duration				0.026
>120 min	31 (31.63)	17(17.89)	3.69	
<120 min	67 (68.36)	39(39.79)		
eRBC transfusion				0.022
>500mL/24	15 (15.30)	12(12.24)	4.36	
>500m<0.05/24	83 (84.69)	36(36.73)		
Inotrops				>0.05
YES	14 (14.28)	7(7.14)	4.14	
NO	84 (85.71)	39(39.63)		

ICU; CPB; CC; MV; RBC; CI, confidence interval

Mechanical ventilation (MV) duration of more than 180 minutes was significantly associated with PRCs (p = 0.026), as was the need for red blood cell (RBC) transfusion >500 mL/24h (p=0.022). The use of inotropic support showed a high odds ratio (OR 4.14), but this association was not statistically significant (p>0.05), indicating a possible trend without sufficient statistical power (Table 3).

Multivariate analysis identified three independent predictors of postoperative respiratory complications: prolonged surgery duration >180 minutes (AOR: 2.33, 95% CI:0.75–10.13; p=0.031), mechanical ventilation >180 minutes (AOR: 4.65, 95% CI:1.34–19.43; p=0.019), blood transfusion >500 ml/24h (AOR: 5.51, 95% CI:1.67–21.76; p=0.016). All reported odds ratios (OR) are adjusted for confounding factors, including preoperative, intraoperative, and postoperative variables (Table 4).

Table 4. Results of multivariate logistic regression analysis of independent risk factors associated with postoperative respiratory complications

Variable	SD	AOR	95%CI (Lower-Upper)	p
Duration of surgery >180 min	0.816	2.37	0.89-9.98	0.034
MV duration >180 min	0.715	4.78	1.51-17.32	0.012
RBC transfusion>500 ml/24 h	0.657	5.21	1.69-23.14	0.008

SD, standard deviation; AOR, adjusted odds ratio; CI, confidence interval;

DISCUSSION

Our analysis applied multivariate logistic regression to control interdependent factors such as ICU stay, duration of surgery, and mechanical ventilation. This approach enabled a more accurate identification of independent predictors, confirming that prolonged surgery, extended mechanical ventilation, and high blood transfusion volume remain key risk factors for postoperative respiratory complications (PRCs).

Over the past decade, advances in cardiac surgery have led to an increased number of complex procedures, often involving patients with multiple comorbidities, which complicates postoperative recovery (14). While many studies focus on preoperative risk factors (15,16), our study emphasizes intraoperative and postoperative contributors, though preoperative variables were also considered.

Diabetes, obesity, smoking, and poor cardiac function were identified as major contributors to increased risk of PRCs (17). Similarly, previous studies have reported comparable findings (18). Our results showed that smoking, female gender, diabetes mellitus, hypertensive heart disease, and low preoperative oxygen saturation (<94%) were significant predictors for the development of PRCs. Although some reports highlight advanced age as a strong determinant of postoperative pulmonary complications (19), our findings diverge from this, instead emphasizing other preoperative and perioperative parameters.

Notably, pneumonia was the most common complication in our group, contrasting with other reports that identify atelectasis as more frequent (20). Our patients with SpO_2<94% had a higher prevalence of respiratory insufficiency postoperatively, underlining the importance of optimizing oxygenation before surgery. Pulmonary complications in our study included pneumonia (25.51%), pleural effusion (15.30%), atelectasis (7.14%), respiratory insufficiency (4.08%), pulmonary oedema (3.06%), and pneumothorax (0.98%). Compared to prior studies, we observed a relatively higher rate of postoperative pneumonia (21).

Interestingly, we found that cardiopulmonary bypass (CPB) time >120 minutes and cross-clamp time >30 minutes were not significant predictors of PRCs. This contrasts with studies that suggest a strong correlation between prolonged CPB and pulmonary complications (22,23). A possible explanation is that bypass preparation and post-CPB management increase total operative time, which indirectly prolongs mechanical ventilation and raises respiratory risk (24). Our findings align with previous reports indicating average CPB times close to 120 minutes.

Prolonged mechanical ventilation remains a major contributor to PRC, and studies have emphasized its impact on delayed extubation and respiratory complications (25,26). This findings underscore the interplay of surgical complexity and critical preoperative condition in elevating risk.

Another key finding of our study was the significant association between blood transfusions >500 ml/24h and PRC. These results emphasize the need for improved perioperative management: limiting surgical duration where feasible, avoiding unnecessary transfusions, and ensuring optimal preoperative oxygenation. This is consistent with Bogović et al., who linked higher transfusion volumes to transfusion-related acute lung injury (TRALI) (27). In addition, patients with prolonged ICU stay showed a higher risk of PRC, supporting earlier findings that associate extended intensive care with increased hospital mortality (28).

This study has several limitations. As a prospective study, it was designed to actively monitor perioperative parameters, but unmeasured confounders may have influenced the results. The single-centre setting may reduce generalizability to other institutions with different protocols or patient profiles. In addition, some relevant intraoperative variables and long-term outcomes were not included due to data constraints. Despite these limitations, the study offers important insights into perioperative factors linked to respiratory complications.

Overall, our findings highlight the multifactorial nature of PRCs, with intraoperative and postoperative factors exerting substantial influence. Future research should focus on individualized risk stratification models integrating dynamic perioperative variables and real-time monitoring. With the evolution of artificial intelligence and machine learning, predictive tools may offer new opportunities for identifying high-risk patients early and personalizing interventions to improve postoperative outcome.

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TRANSPARENCY DECLARATION

Conflict of interest: Non to declare.

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