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Are respiratory risks after cardiac surgery universal? A case study from Tuzla, Bosnia and Herzegovina

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ABSTRACT

Objective: Postoperative respiratory complications (PRCs) are a significant concern after cardiac surgery, contributing to increased morbidity and mortality. This study aimed to analyze the incidence and risk factors for PRCs in a tertiary center in Bosnia and Herzegovina and compare findings with data from developed countries.

Material and Methods: This prospective cohort study included 300 adult patients who underwent open-heart surgery with cardiopulmonary bypass at the Clinic for Cardiovascular Surgery, University Clinical Center Tuzla, between January 2020 and October 2023. Preoperative, intraoperative, and postoperative variables were analyzed, including comorbidities, surgical procedures, mechanical ventilation duration, and intensive care unit stay. PRCs were defined based on standardized clinical and radiological criteria. Multivariate logistic regression identified independent risk factors.

Results: The most common PRCs were pneumonia (37.3%), atelectasis (29.3%), pleural effusion (22.0%), and respiratory failure (10.7%). Key independent risk factors included oxygen saturation <94%, ejection fraction <45%, diabetes mellitus, anemia, and red blood cell transfusion >500 mL. In contrast to studies from developed countries, intraoperative variables were not significant predictors.

Conclusion: Our findings suggest that preoperative comorbidities play a more dominant role in PRC development in our setting compared to developed nations. The high incidence of pneumonia may reflect delayed postoperative mobilization and limited access to respiratory therapy. These results underscore the need for optimized preoperative patient management and improved postoperative respiratory care protocols in resource-limited healthcare settings.

Keywords: Postoperative respiratory complications, pneumonia, cardiac surgery, risk factors, developing countries

INTRODUCTION

Postoperative respiratory complications (PRCs) remain a leading cause of morbidity and mortality following cardiac surgery, significantly impacting patient outcomes and healthcare resource utilization. The incidence of PRCs varies widely across studies, with reported rates ranging from 2.1% to 21.6% in developed countries, while some studies from resource-limited settings suggest even higher rates (1,2). PRCs are associated with prolonged mechanical ventilation, increased intensive care unit (ICU) stay, and higher in-hospital mortality (15-45%), making their prevention and management a priority in perioperative care (3). The European Perioperative Clinical Outcome guidelines define PRCs as a spectrum of conditions, including pneumonia, atelectasis, pleural effusion, pneumothorax, bronchospasm, aspiration pneumonitis, acute respiratory distress syndrome, and pulmonary embolism (4). These complications are particularly prevalent in elderly patients and those with significant preexisting comorbidities, further complicating postoperative recovery (5,6). The development of PRCs is multifactorial, influenced by a combination of preoperative, intraoperative, and postoperative factors. Preoperative risk factors such as smoking, chronic obstructive pulmonary disease (COPD), diabetes mellitus, low ejection fraction (EF), and anemia have been widely recognized (7,8). Intraoperative factors, including prolonged cardiopulmonary bypass (CPB) time, anesthesia, blood transfusions, and fluid overload, also contribute to postoperative pulmonary dysfunction (9-11). Postoperatively, factors such as mechanical ventilation duration,

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delayed extubation, and ICU-acquired infections further increase the risk of PRCs (12). Despite advancements in perioperative management, PRCs continue to pose a challenge in both developed and developing countries. However, differences in healthcare infrastructure, patient populations, and perioperative protocols may result in variability in risk factors and outcomes. While studies from high-resource settings emphasize intraoperative and postoperative factors, emerging evidence suggests that preoperative comorbidities may play a more dominant role in developing countries (13,14). This study aims to analyze the incidence and risk factors for PRCs in patients undergoing cardiac surgery at a tertiary center in a developing country and compare the findings with studies from developed nations. Identifying modifiable risk factors specific to our patient population may help guide preventive strategies and optimize perioperative management to improve outcomes.

MATERIAL and METHODS

This prospective cohort study included 300 consecutive adult patients who underwent open-heart surgery with CPB at the Clinic for Cardiovascular Surgery, University Clinical Center Tuzla, between November 2020 and October 2023. The study was conducted in accordance with ethical principles and was approved by the Ethics Committee of the University Clinical Center Tuzla (approval no: 02-09/2-65/20, date: November 4, 2020).

Inclusion criteria: Adult patients (≥18 years) undergoing elective or urgent coronary artery bypass grafting (CABG), aortic valve replacement (AVR), mitral valve replacement (MVR), or the Bentall procedure.

Exclusion criteria: Patients witha history of previous thoracic surgery, AMI within 30 days before surgery, or pre-existing severe respiratory failure requiring prolonged ventilation (>48 h) before surgery (Figure 1).

Data collection: Clinical and demographic data were collected from the hospital's electronic medical record system. The following variables were analyzed:

Preoperative variables: [Age, sex, smoking history, body mass index (BMI), diabetes mellitus, hypertension, COPD, left ventricular EF, hemoglobin levels (anemia), and preoperative oxygen saturation (SpO_2)]. COPD was defined according to the GOLD guidelines as FEV_1/FVC <0.7 post-bronchodilator (15).

Anemia was defined according to World Health Organization criteria as hemoglobin <13 g/dL for men and <12 g/dL for women (16). Intraoperative variables: Duration of CPB and aortic cross-clamp time, type of cardiac surgery performed, red blood cell (RBC) transfusions (>500 mL/24 h). Postoperative variables: Length of mechanical ventilation and ICU stay (≥48 h vs.<48 h). Respiratory complications including pneumonia, atelectasis, pleural effusion, pneumothorax were assessed according to the ERS/ESICM/ESCMID/ALAT guidelines (17). Pneumonia was defined based on radiographic evidence of new infiltrates and at least two of the following criteria: Fever >38°C, leukocytosis (>12×10^9/L), purulent respiratory secretions, and positive microbiological cultures from endotracheal aspiration. Atelectasis, pleural effusion, pneumothorax, and pulmonary edema were diagnosed using chest radiography and clinical criteria.

Statistical Analysis

Descriptive statistics: Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as percentages. Comparative analysis: Student's t-test was used for continuous variables, and the chi-square test was used for categorical variables. Multivariate logistic regression: Variables with p<0.1 in univariate analysis were included in a multivariate model to identify independent predictors of PRCs. A p-value <0.05 was considered statistically significant. Software used: All statistical analyses were performed using IBM SPSS statistics version 25.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Among the 300 patients included in the study, 211 (70.5%) were male and 89 (29.5%) were female. The mean age of male patients was 61.35±15.2 years, while the mean age of female patients was 55.43±12.9 years. The distribution of surgical procedures was as follows: CABGfor 98 patients (32.7%), AVR for 69 patients

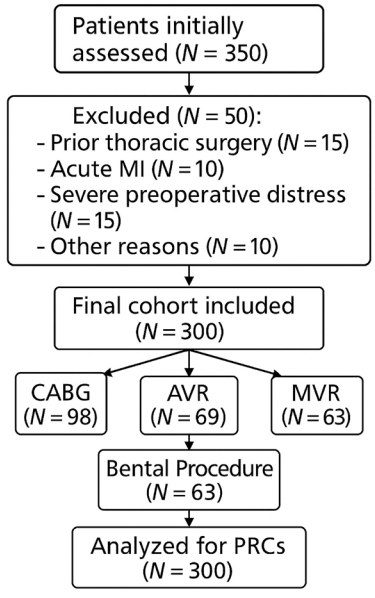

Figure 1. Flowchart of patients selection and data collection.

CABG: Coronary artery bypass grafting, AVR: Aortic valve replacement, MVR: Mitral valve replacement, PRCs: Postoperative respiratory complications

(23.0%), MVRfor 34 patients (11.3%), and Bentall procedure for 63 patients (21.0%).

Table 1. Distribution of postoperative respiratory complication in the study population

Complications	Patients (no)	Percentage (%)
Pneumonia	112	37.3
Atelectasis	88	29.33
Pleural effusion	66	22.00
Respiratory failure	32	10.66
Pulmonary edema	17	5.66
Pneumothorax	9	3.00

PRCs were observed in a significant proportion of patients (Table 1). The most common were pneumonia (37.3%), atelectasis (29.3%), pleural effusion (22.0%), followed by respiratory failure (10.7%), pulmonary edema (5.7%), and pneumothorax (3.0%). The incidence of pneumonia in our study was considerably higher than reports from developed countries.

Univariate analysis identified several preoperative risk factors significantly associated with the development of PRCs, including smoking, diabetes mellitus, COPD, elevated BMI, reduced EF, anemia, and low oxygen saturation. Conversely, age and urgency of surgery were not found to be significant predictors (Table 2).

Table 2. Univariate analysis of preoperative risk factors for postoperative respiratory complications

Variable		Patients (no)	30-day morbidity	OR (CI-95%)	p-value
Sex					
	Men	211	114	2.40	0.05
	Women	89	60		
Smoking					
	Yes	157	147	3.97	0.001
	No	143	25		
Age					
	<65 yr	159	100	1.49	0.05
	>65 yr	141	74		
Diabetes mellitus					
	Yes	151	135	5.00	0.001
	No	149	41		
Hypertension					
	Yes	244	148	3.75	0.01
	No	56	26		
COPD					
	Yes	82	56	2.00	0.049
	No	218	118		
BMI					
	<25 kg/m^2	199	134	3.33	0.029
	>25 kg/m^2	101	40		
EF <45%					
	Yes	18	11	5.32	0.001
	No	282	7		
[b]Anemia					
	Yes	31	25	4.54	0.01
	No	269	149		
Oxygen saturation					
	<94%	58	50	6.48	0.015
	>94%	242	124		
Urgent procedure					
	Yes	24	15	0.81	0.05
	No	276	159		

EF: Ejection fraction, [b]: Definition of anemia has been updates accorfing to the WHO recommendations (Hb <13 g/dL for men and <12 g/dL for non-pregnant women, Htc <38% for men and <36% for women), OR: Odds ratio, Hb: Hemoglobin, WHO: World Health Organization, CI: Confidence interval, Htc: Hydrochlorothiazide, BMI: Body mas index, COPD: Chronic obstructive pulmonary disease.

Univariate analysis identified, several intraoperative and postoperative factors significantly associated with PRCs, including prolonged operation duration, increased RBC transfusion volume, extended mechanical ventilation, and longer ICU stay. Conversely, CPB duration and pleural cavity opening did not demonstrate statistical significance (Table 3).

Multivariate logistic regression analysis identified preoperative hypoxia SpO_2 <94% (p=0.015), reduced EF <45% (p=0.001), diabetes mellitus (p=0.001), anemia (p<0.01), transfusion>500 mL (p<0.002), smoking (0.001), and hypertension (<0.01) as independent risk factors for postoperative respiratory complication (Table 4).

Table 5 presents the most common PRCs following cardiac surgery and identifies independent risk factors associated with these complications based on multivariate analysis. The data include multiple studies analyzing respiratory outcomes in different cohorts of cardiac surgery patients. The key finding from the table is that Pneumonia was the most frequently reported PRC, with incidence rates ranging from 3.0% to 37.3% across studies. Other common complications included atelectasis (10-29.3%), pleural effusion (22%), respiratory failure (10.7-21%), and pneumothorax (3-4%). Independent risk factors for PRCs included preoperative hypoxia (SpO_2 <94%), low EF, anemia, diabetes mellitus, prolonged mechanical ventilation, transfusion of RBCs (>500 mL), and reintubation.Multivariate analysis indicated that factors such as age, COPD, EuroSCORE II, and prolonged CPB time were significantly associated with higher PRC rates (p<0.05). The study reported the highest pneumonia rate (37.3%) and identified SpO_2, diabetes, and hypertension as major contributors.

Table 3. Univariate analysis of intraoperative and postoperative risk factors for postoperative respiratory complications

Variable	PRCs (%)	OR (95% CI)	p-value
Operation duration >180	34.3	2.23	<0.05
CPB >180 min	21.33	0.35	>0.05
Circulatory arrest >30 min	3.66	0.27	>0.05
Opening of the pleural cavity	19.0	0.28	>0.05
Mechanical ventilation >24 h	18.0	3.69	0.026
Transfusion>500 mL	13.0	4.35	0.022
ICU stay >48 h	30.3	2.18	<0.05

CPB: Cardiopulmonary bypass, ICU: Intensive care unite, OR: Odds ratio, CI: Confidence interval, PRCs: Postoperative respiratory complications.

Table 4. Multivariate analysis of independent risk factors for postoperative respiratory complications

Variable	OR (95% CI)	p-value
Preoperative SpO_2<94%	6.48	0.015
Ejection fraction <45%	5.32	0.01
Diabetes mellitus	5.00	0.01
Anemia	4.54	<0.01
Transfusion >500 mL	4.35	<0.02
Smoking	3.79	0.01
Hypertension	3.75	<0.01

OR: Odds ratio, CI: Confidence interval.

DISSCUSION

Our study reported a 37.3% incidence of pneumonia, which is significantly higher than rates observed in developed countries [6.26% in Piotto et al. (18), 3.1% in Allou et al. (19), and 0.58% in Naveed et al. (20)] (Table 5). Several factors may explain this discrepancy:

1. While delayed postoperative mobilization can have adverse effects, early ambulation is a key strategy for preventing pneumonia. In our setting, limitations in postoperative physiotherapy resources may have contributed to prolonged immobilization.

2. Limited respiratory therapy activation: In developed countries, standardized pulmonary rehabilitation protocols are initiated early, whereas in our center, the availability of respiratory therapists is limited.

3. Higher burden of preoperative comorbidities: Many of our patients had poorly controlled diabetes, hypertension, and pre-existing COPD, which increased their susceptibility to PRCs.

4. Variability in diagnostic criteria: While some studies required microbiological confirmation, our study relied on radiographic and clinical criteria, which may have resulted in a higher detection rate.

Preoperative vs. Intraoperative Risk Factors

A key finding in our study is that preoperative comorbidities are the dominant risk factors for PRCs, unlike studies in developed countries where intraoperative factors (CPB time, pleural cavity opening, reintubation) play a more significant role (21). Oxygen saturation <94%, EF <45%, diabetes, and anemia were the most significant independent predictors of PRCs (Table 4). Smoking, hypertension, and RBC transfusions (>500 mL/24 h) were also associated with PRCs. Intraoperative factors such as CPB duration and pleural cavity opening were not significant predictors, suggesting that our surgical techniques are comparable to those in developed countries. These findings highlight the need for improving preoperative management, including better screening for high-risk patients, early interventions for comorbidities, and optimized perioperative strategies.

Age as a risk factor: Why was it not significant? Contrary to most studies, age was not a significant predictor of PRCs in our cohort. Possible explanations include: Selection bias - younger patients with multiple comorbidities may have been included

in the surgical group, while older patients with poor prognosis may have been excluded from surgery. Differences in risk stratification - Some studies included redo surgeries, which are more common in elderly populations, whereas our study primarily analyzed first-time cardiac surgeries (22). Despite these findings, age remains an important clinical consideration and should not be disregarded in perioperative risk assessment.

Comparison with Developed Countries

Table 5 compares our findings with major studies from high-resource settings. The key takeaways include: PRC rates (especially pneumonia) were significantly higher, likely due to resource limitations, slower patient mobilization, and differences in healthcare infrastructure. Preoperative factors dominated in our study, whereas intraoperative and postoperative factors were found to be more significant in developed countries (23,24). Smoking and anemia were stronger predictors in our cohort, possibly due to higher baseline prevalence and inadequate preoperative correction (25).

Clinical Implications for Developing Countries

Based on our findings, the following strategies may help reduce PRCs in resource-limited settings: Improvement of preoperative disease control, such as better glycemic control, hypertension management, and anemia correction before surgery. Optimizing respiratory therapy - increasing the number of trained respiratory therapists and implementing standardized pulmonary care protocols (26,27).

Study Limitations

Several limitations should be considered when interpreting our findings. First, this study was conducted at a single center, which may limit the generalizability of the results to other

Table 5. Most common postoperative respiratory complications after cardiac surgery and multivariate analysis of risk factors

Author	n	Type of study	Procedure	Respiratory complications, n (%)	Independent risk factors, OR, p-value
Our study	300	Prospective	Cardiac surgery	Pneumonia, 112 (37.3) Atelectasis, 88 (29.33) Pleural effusion, 66 (22) Respiratory failure, 32 (10.66) Pulmonary edema, 17 (5.66) Pneumothorax, 9 (3)	Preoperative [c]SO_2, OR: 6.48, p<0.015 Ejection fraction, OR: 5.32, p=0.001 Diabetes mellitus, OR: 5.00, p=0.001 Anemia, OR: 4.54, p<0.01 Transfusion of [d]RBC >500 mL, OR: 4.35, p<0.002 Smoking, OR: 3.97, p=0.001 Hypertension, OR: 3.75, p<0.01
Piotto et al. (18)	2952	Prospective	[a]CABG	[b]ARDS, 11 (0.37) Pulmonary embolism, 7 (0.2) Pneumonia, 185 (6.26) Other pulmonary, 15 (0.50)	Age, OR: 1.06, p<0.001 [e]CRF, OR: 3.52, p<0.001 [f]COPD, OR: 2.65, p=0.004 CABG associated with other procedures, OR: 3.33, p<0.001 Clamping time, OR: 1.01, p=0.018
Allou et al. (19)	5582	Cohort	Cardiac surgery	Pneumonia, 174 (3.1)	Age, OR: 1.02, p=0.013 COPD, OR: 3.08, p<0.0001 Ejection fraction, OR: 0.98; p=0.009 Duration of [g]CPB, OR: 1.01, p<0.0001 Transfusion of RBC, OR: 1.67, p=0.03
Naveed et al. (20)	517	Prospective observational	Cardiac surgery	Pneumonia, 3 (0.58) Atelectasis, 20 (3.86) Respiratory failure, 8 (1.54) ARDS, 1 (0.19)	Age, OR: 4.16, p<0.001 Pre-op pulmonary hypertension, OR: 2.60, p=0.014 CPB time >120 minutes, OR: 3.62, p=0.003 Phrenic nerve injury, OR: 7.06; p=0.002
Fischer et al. (7)	676	Cohort	Cardiac surgery	Atelectasis, 111 (16) Pleural effusion, 220 (32) Respiratory failure, 141 (21%) Respiratory infection, 63 (9) Pneumothorax, 30 (4) Bronchospasm, 10 (1) Aspiration pneumonitis, 7 (1)	Age, OR: 1.09, p=0.044 EuroSCORE II, OR:1.09, p=0.010 COPD, OR: 3.14, p<0.001 CABG, OR: 0.62, p=0.016 Pressure support ventilation with PEEP, OR: 0.53, p=0.070
Urquiza et al. (3)	211	Prospective	Cardiac surgery	Pneumonia, 31 (14.6)	Hypertension, OR: 3.94, p=0.01 CRF, OR: 13.67, p=0.02 Reintubation, OR: 22.29, p=0.001 Extubation after 6 h, OR: 15.81, p=0.005

[a]CABG: Coronary artery bypass grafting, [b]ARDS: Acute respiratory distress syndrome, [c]SO_2: Oxygen saturation, [d]RBC: Red blood cells, [e]CRF: Chronic renal failure (creatinine >2 mg/dL), [f]COPD: Chronic obstructive pulmonary disease, [g]CPB: Cardiopulmonary bypass, OR: Odds ratio, CI: Confidence interval.

healthcare settings. Additionally, the diagnosis of pneumonia relied on clinical and radiographic criteria, potentially leading to an overestimation of cases. Another limitation is the lack of long-term follow-up, preventing an assessment of prolonged pulmonary outcomes. Lastly, as this was an observational cohort study, the absence of prospective trial registration highlights the need for future randomized trials to confirm these findings.

Our study identified preoperative comorbidities as the dominant risk factors for PRCs. Among them, oxygen saturation <94%, EF <45%, and diabetes mellitus were the most significant predictors. In contrast, intraoperative factors (CPB duration, pleural cavity opening) were not significant, suggesting that surgical techniques in our setting are comparable to those in developed countries. The incidence of pneumonia (37.3%) in our cohort was significantly higher than in developed countries [6.26% in Piotto et al. (18), 3.1% in Allou et al. (19), and 0.58% in Naveed et al. (20)] (Table 5). This discrepancy can be explained by delayed postoperative mobilization due to limited physiotherapy resources. There is limited access to respiratory therapy compared to standardized pulmonary rehabilitation programs in developed countries. Higher burden of preoperative comorbidities (diabetes, hypertension, COPD). Differences in pneumonia diagnostic criteria were observed, as our study relied on radiographic and clinical findings rather than microbiological confirmation (28,29). These findings emphasize the importance of optimizing preoperative risk assessment and perioperative management to minimize respiratory complications in cardiac surgery patients, particularly in resource-limited settings.

CONCLUSION

This study challenges the assumption that postoperative respiratory risks after cardiac surgery are universal. Our findings from Tuzla, Bosnia and Herzegovina, demonstrate a higher incidence of PRCs, particularly pneumonia (37.3%), compared to that in developed countries. This discrepancy suggests that risk factors and management strategies from high-resource settings may not be directly applicable to developing healthcare systems.

Unlike studies from developed nations, where intraoperative and postoperative factors play a dominant role, our results highlight preoperative comorbidities -low oxygen saturation, reduced EF, diabetes, and anemia- as the primary risk factors. These findings underscore the urgent need for tailored perioperative strategies that account for regional differences in healthcare resources, patient populations, and postoperative care protocols. Simply adopting risk models and treatment protocols from developed countries may not effectively address the unique challenges faced in resource-limited settings. To improve outcomes, a context-specific approach is essential, with emphasis on early risk assessment, preoperative optimization, structured pulmonary care, and early mobilization. Future research should focus on adapting and validating evidence-based strategies to bridge the gap between different healthcare environments and ensure more equitable surgical outcomes worldwide.

Ethics

Ethics Committee Approval: The study was conducted in accordance with ethical principles and was approved by the Ethics Committee of the University Clinical Center Tuzla (approval no: 02-09/2-65/20, date: November 4, 2020).

Informed Consent: Prospective study.

Footnotes

Author Contributions

Concept -A.K.; Design - A.K., A.S., O.K.; Fundings - A.K., A.S., I.I.; Materials - A.K., A.S.; Data Collection or Processing - A.K., A.S., O.K.; Critical Review-O.K.; Literature Search -A.S., I.I.; Writing -A.K.

Conflict of Interest: No conflict of interest was declared by the authors.

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