Original Article

Risk Factors for Pulmonary Complications in Patients With Cardiac Surgery in a Tertiary Heart Center

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ABSTRACT

Background: Postoperative pulmonary complications (PPCs) are among the leading causes of morbidity, mortality, and increased length of stay (LOS).

Methods: In a prospective cohort study, all adult candidates for all types of open-heart surgeries were enrolled and followed from admission to discharge for PPCs.

Results: The study population consisted of 918 consecutive adult patients, including 574 (62.5%) males, at a mean age of 56.20±13.95 (mean ± standard deviation) years who underwent open cardiac surgery. Among them, 537 patients (58.5%) suffered PPCs, comprising pleural effusion in 293/916 (32.0%), atelectasis in 222 (24.2%), pneumonia in 68 (7.4%), diaphragm paralysis in 67 (7.3%), pulmonary edema and/or acute respiratory distress syndrome in 64/915 (7.0%), pneumothorax (in the right or left hemithorax) in 28/916 (3.1%), hemothorax in 7/915 (0.8%), subcutaneous emphysema in 11/913 (1.2%), and empyema in 2/918 (0.2) The independent risk factors for PPCs were age (OR, 1.010; 95% CI, 1.001 to 1.020; *P*=0.0326), female sex (OR, 1.375; 95% CI, 1.044 to 1.811; *P*=0.0235), and renal dysfunction (OR, 1.553; 95% CI, 1.001 to 2.409; *P*=0.0497). Twenty-three patients died within 30 days of cardiac surgery, accounting for a hospital mortality rate of 2.5%.

Conclusions: The cumulative incidence rate of PPCs was 58.5% in our center, with a mortality rate of 3.4%. The overall mortality rate among all the patients was 2.5%. The independent risk factors associated with PPCs were age, female sex, and renal failure. ***(Iranian Heart Journal 2023; 24(2): 35-44)***

KEYWORDS: Pulmonary function tests, Postoperative pulmonary complication, Risk factors, cardiac Surgery

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Postoperative pulmonary complications (PPCs) are among the leading causes of morbidity, mortality, and increased length of stay (LOS) in hospitals in patients undergoing cardiac surgery. [1] PPCs are common following coronary artery bypass graft surgery (CABG), adult congenital heart surgery, and especially in the replacement of diseased valves, and they often lead to prolonged LOS in hospitals, increased cost of surgery, and mortality. [2, 3]

The various components of the respiratory system, namely airways, lungs, chest wall, intercostal muscles, diaphragm, and neural pathways, may be damaged by a variety of processes of cardiac surgery, including the operation itself, cardiopulmonary bypass, and postoperative management and procedures. In addition, previous lung diseases may affect the function of the pulmonary system postoperatively. [4, 5] Furthermore, changes in the systemic and pulmonary blood pressures and allergic reactions to drugs and oxygenator membranes may increase capillary permeability, leading to alveolar edema and acute respiratory distress syndrome (ARDS), while mechanical problems may occur following phrenic nerve damage. [4,5] Atelectasis, pleural effusion, pulmonary embolism, pneumonia, diaphragm paralysis, and ARDS are the most important pulmonary complications after cardiac surgery. [1,2,4-6]

Factors affecting the development of PPCs are related to the prior health status of the patient, the effects of anesthesia, and intraoperative events. Because of these wide and varied factors, the incidence rate of pulmonary complications after heart surgery varies dramatically. [7] The achievement of an adequate preoperative evaluation of pulmonary risk may reduce such complications with appropriate measures, leading to reduced perioperative morbidity and hospital LOS and costs. [8]

Notwithstanding the importance and frequency of pulmonary complications, our knowledge of the perioperative factors that increase the risk of these complications after cardiac surgery is limited. In this study, our objectives were to determine the incidence of PPCs after different cardiac surgeries and investigate the perioperative clinical and laboratory factors and pulmonary variables that are associated with PPCs in patients undergoing non-emergency cardiac surgery at a tertiary university hospital. We also sought to determine the independent risk factors that might assist in the prediction of PPCs.

METHODS

This prospective cohort study aimed to determine the incidence of PPCs after cardiac surgery and investigate the perioperative clinical and laboratory factors as well as pulmonary function variables that are associated with PPCs in patients undergoing non-emergency cardiac surgery at Rajaie Cardiovascular Medical and Research Center (RHC), a tertiary university hospital.

From September 10, 2016, through March 10, 2017, all consecutive adult patients aged above 15 years who were candidates for CABG, congenital heart surgery, or valve surgery in RHC were enrolled and followed from admission to discharge. Patients who underwent emergency surgery were excluded. The study conduct adhered to the Helsinki Protocol, and the study protocol was approved by the institutional ethics committee. All the expenses were covered by Iran University of Medical Sciences.

Demographic data; a history of comorbid diseases such as diabetes mellitus, renal failure, and respiratory diseases; and the results of laboratory and pulmonary function tests were obtained from the patients' hospital files or were asked directly from them. Complete history, vital signs, clinical examinations, chest X-rays (CXRs), pulse oximetry, electrocardiography, echocardiography, and complete blood tests were taken, as a routine practice, to determine the patients' status.

Before surgery, all the patients underwent blood gas analysis in the operating room, first on air and then after 15 minutes on 100% oxygenation (while on the ventilator); the information was recorded in a special chart. As a routine practice, all the patients received general anesthesia and were placed on pump oxygenators during surgery. All the surgeries were performed via median sternotomy. Cold blood cardioplegia was used for cardiac arrest. In our intensive care unit (ICU), the patients are routinely extubated when they are hemodynamically stable and able to breathe adequately. After extubation, oxygen saturation (SPO_2) is maintained above 90% with supplemental oxygen through the mask or nasal cannula, and patients can leave their beds as soon as their general condition and tubing status permit it. Blood culture and special evaluations are provided if patients develop complications requiring diagnostic tests or procedures.

The rate of the total incidence of PPCs was obtained by gathering the frequencies of all morbidities at 24, 48, and 72 hours after surgery; after ICU discharge; and before hospital discharge.

All the patient's CXRs and computerized tomography (CT) scans were reviewed by our expert pulmonologist. The diagnosis of atelectasis was made and categorized if it was present in at least 1 of the radiographs or CT scans of the patients at the time of ICU admission. Plate atelectasis, lobar atelectasis, multilobar atelectasis, and total 1-lung collapse were all considered to be atelectasis.

Pleural effusion was diagnosed based on CXRs if the blunting of the costophrenic angle and opacity were noted to have filled at least 2 interspaces, or if hazy opacity was observed in 1 hemithorax in the supine position with preserved vascular shadows. Effusion on CT, echocardiography, and sonography was also regarded as pleural effusion if these procedures were performed for other reasons and showed effusion in the pleural space even if effusion was not found in radiography. All the suspected cases on CXRs were confirmed via the sonography of both hemithoraces.

The diagnosis of hospital-acquired or ventilator-associated pneumonia was based on the presence of new pulmonary infiltrates on CXRs or CT scans, fever, and cough or sputum after surgery and if antibiotics were started for pulmonary infiltrates at the discretion of the pulmonologist or the infectious disease specialist. Given the high incidence of leukocytosis after these kinds of operations, hospital-acquired pneumonia in our patients was considered if they had at least 2 of the above findings plus leukocytosis. Ventilator-associated pneumonia was considered if the patient remained intubated for more than 48 hours and had the criteria of pneumonia.

The diagnosis of ARDS/pulmonary edema was based on the radiographic findings and clinical conditions of the patients. It was impossible to follow the Berlin definition of ARDS and, therefore, pulmonary edema and ARDS were considered to be 1 entity.

Diaphragm dysfunction or paralysis was diagnosed if significant permanent diaphragm elevation was seen on CXRs and/or ultrasonography confirmed the loss of diaphragm muscle contraction or significantly decreased motion. Phrenic nerve conduction velocity measurement and diaphragm electromyography were not feasible at our center.

Statistical Analysis

The results are presented as the mean ± the standard deviation (SD) for the numeric variables and are indicated as absolute frequencies and percentages for the categorical variables. The numeric variables were compared using the independent 2-sample *t*-test, while the categorical variables were compared using the χ^2 or Fisher exact test, as appropriate, between the 2 groups of PPCs and non-PPCs.

The normality of the frequency distribution of the quantitative variables was checked using the nonparametric Shapiro–Wilk test (*P*>0.05), and the skewness of the frequency distribution of the numeric variables was laid within ± 2 in either group.

A multivariable backward logistic regression model for the factors associated with PPCs was constructed. The associations between the independent predictors and PPCs in the final model were presented as odds ratios (ORs) with 95% confidence intervals (CIs). Model discrimination was assessed using the C statistic, which is equal to the area under the receiver operating characteristic (ROC) curve, with higher C values indicating useful discrimination of the model. Model calibration was appraised using the Hosmer–Lemeshow goodness-of-fit statistic, with higher *P* values showing that the model fitted the observed data better. Some important interaction terms were also introduced into the model, but they were all dropped as they failed to reach the significance level of 0.05.

For the statistical analyses, the statistical software SPSS, version 22.0, for Windows (SPSS Inc, Chicago, IL, USA) and the statistical package SAS, version 9.2, for Windows (SAS Institute Inc, Cary, NC, USA) were utilized. All *P* values were considered 2-tailed, with the statistical level set at 0.05.

RESULTS

Between September 2016 and March 2017, a total of 918 consecutive adult patients, including 574 (62.5%) males, at a mean age of 56.20±13.95 (mean ± SD) years who underwent cardiac surgery were studied, and their data were analyzed. Among them, 537 patients (58.5%) developed PPCs (95% CI, 56.9% to 60.1%). Among those with PPCs, pleural effusion was detected in 293/916 patients (32.0%), atelectasis in 222 (24.2%), pneumonia in 68 (7.4%), diaphragm paralysis in 67 (7.3%), pulmonary edema and or ARDS in 64/915 (7.0%), pneumothorax (in the right or left hemithorax) in 28/916 (3.1%), hemothorax in 7/915 (0.8%), subcutaneous emphysema in 11/913 (1.2%), and empyema in 2/918 (0.2%).

Female sex and renal dysfunction were more prevalent in the PPC group than in the non-PPC group (*P*=0.029 and *P*=0.047, respectively), while smoking was more common in the non-PPC group than in the patients with PPCs (*P*=0.024). Additionally, those with PPCs were older and had a lower estimated glomerular filtration rate (eGFR) than the non-PPC group (*P*=0.035 and *P*=0.022, correspondingly) (Table 1).

A multivariable backward logistic regression model was applied to determine the independent risk factors for PPCs. Variables with a *P* value of less than 0.20 obtained via the univariable analysis (Table 1) were then entered into the multivariable model. As is depicted in Table 2, the independent risk factors for PPCs were age (OR, 1.010; 95% CI, 1.001 to 1.020; *P*=0.0326), female sex (OR, 1.375; 95% CI, 1.044 to 1.811; *P*=0.0235), and renal dysfunction (OR, 1.553; 95% CI, 1.001 to 2.409; *P*=0.0497).

Twenty-three adult patients died within 30 days of cardiac surgery, accounting for a hospital mortality rate of 2.5%. Although the death rate was higher in the PPC group (18 [3.4%]) than in the non-PPC group (5 [1.3%]), the difference failed to constitute statistical significance (OR, 2.608; 95% CI, 0.960 to 7.087; *P*=0.051). On the other hand, the mean hospital LOS was 16.53±8.17 days in the entire study population, such that in the PPC group, it was significantly longer (16.98±8.40 d) than that in the non-PPC group (15.90 ± 7.80 d) (*P*=0.047) (Table 3).

Intubation duration was recorded just for a total of 886 patients with a mean of

750.46±670.47 minutes: 760.96±697.45 minutes in 518 patients with PPCs and 735.69±631.19 minutes in 381 patients without PPCs (*P*=0.581).

Table 1: Baseline characteristics of the patients who underwent cardiac surgery in RHC between September 2016 and March 2017 (N=918)

Characteristic	All Patients (N=918)	PPCs (n=537)	Non-PPCs (n=381)	*P* value
Preoperative				
Age (y)	56.20±13.95	57.02±3.42	55.05±4.81	0.035
Age Groups (y)				0.032
≤45	178 (19.4)	88 (16.4)	90 (23.6)	
46-55	194 (21.1)	123 (22.9)	71 (17.6)	
56-65	305 (33.2)	178 (33.1)	127 (33.3)	
≥66	241 (26.3)	148 (27.6)	93 (24.4)	
Sex				0.029
male	574 (62.5)	320 (59.6)	254 (66.7)	
female	344 (37.5)	217 (40.4)	127 (33.3)	
BMI (kg/m^2)	26.62±4.61	26.65±4.44	26.58±4.84	0.806
Smoking	290 (31.6)	154 (28.7)	136 (35.7)	0.024
Hookah use	38 (4.1)	26 (4.8)	12 (3.1)	0.205
Home bakery	122 (13.3)	80 (14.9)	42 (11.0)	0.088
Opium use	164 (17.9)	85 (15.8)	79 (20.7)	0.056
Renal dysfunction	102 (11.1)	69 (12.8)	33 (8.7)	0.047
Diabetes	247 (26.9)	157 (29.2)	90 (23.6)	0.059
Hypertension	328 (35.7)	190 (35.4)	138 (36.2)	0.794
History of witnessed apnea	126 (13.7)	76 (14.2)	50 (13.1)	0.655
History of snoring	441 (48.0)	254 (47.3)	187 (49.1)	0.594
History of morning fatigue	368 (40.1)	215 (40.0)	153 (40.2)	0.971
History of nocturnal suffocation	101 (11.0)	50 (9.3)	51 (13.4)	0.051
ESS	3.02±4.42	3.03±4.45	3.01±4.39	0.924
ESS Groups				0.730
0	517 (56.3)	304 (56.6)	213 (55.9)	
1-5	305 (33.2)	174 (32.4)	131 (34.4)	
> 5	96 (10.5)	59 (11.0)	37 (9.7)	
ASA Class				0.464
I	154 (16.8)	96 (17.9)	58 (15.2)	
II	423 (46.1)	241 (44.9)	182 (47.8)	
III	238 (25.9)	144 (26.8)	94 (24.7)	
IV	103 (11.2)	56 (10.4)	47 (12.3)	
Neck circumference (cm)	37.02±3.44	36.94±3.40	37.12±3.51	0.423
SPAP Groups (cmH_2O)				0.151
≤ 25	693 (75.5)	418 (77.8)	275 (72.2)	
26-35	153 (16.7)	77 (14.3)	76 (19.9)	
36-45	51 (5.6)	29 (5.4)	22 (5.8)	
≥ 46	21 (2.3)	13 (2.4)	8 (2.1)	
Diastolic dysfunction	159 (17.3)	86 (16.0)	73 (19.2)	0.215
EF (%)	42.34±10.13	42.76±10.02	41.76±10.26	0.141
FEV1 (percent predicted)	94.66±17.24	95.21±17.36	91.89±16.35	0.248
FVC (percent predicted)	92.94±16.96	93.72±17.36	91.89±16.35	0.108
FEV1/FVC (percent predicted)	106.63±12.11	106.13±12.68	107.33±11.24	0.137
MMEF (percent predicted)	85.37±27.56	85.06±28.28	85.80±26.88	0.690
FBS (mg/dL)	115.21±52.54	115.54±57.14	114.74±45.33	0.819
eGFR	77.48±30.99	75.50±30.18	80.26±31.92	0.022
BUN (mg/dL)	19.88±8.82	20.07±8.54	19.61±9.20	0.428
Uric acid (mg/dL)	6.49±1.84	6.59±1.90	6.36±1.74	0.068

Intraoperative				
Type of Surgery CABG Valvular Large vessels Adult congenital	626 (68.2) 246 (26.8) 18 (2.0) 28 (3.1)	360 (67.0) 146 (27.2) 12 (2.2) 19 (3.5)	266 (69.8) 100 (26.2) 6 1.6) 9 (2.4)	0.608
Clamp time (min)	54.28±27.68	55.64±27.96	52.38±27.21	0.079
Pump time (min)	91.97±40.90	93.84±41.72	89.48±39.64	0.120
Skin-to-skin time (min)	246.22±73.70	247.96±72.25	244.15±75.76	0.475
Blood product transfusion	605 (65.9)	355 (66.1)	250 (65.6)	0.877

Data are presented as mean ± SD or n (%).
ESS, Epworth Sleepiness Scale; ASA, The American Society of Anesthesiologists; RHC, Rajaie Cardiovascular Medical and Research Center; PPCs, Postoperative pulmonary complications; BMI, Body mass index; SPAP, Systolic pulmonary artery pressure by echocardiography; EF, Ejection fraction of the left ventricle; FEV1, Ejection fraction at first second; FVC, Forced vital capacity; MMEF, Maximum expiratory flow rate; FBS, Fasting blood sugar; eGFR, Estimated glomerular filtration rate; BUN, Blood urea nitrogen; CABG, Coronary artery bypass graft surgery

Table 2: Independent risk factors for PPCs (N=918)

Variable	Unadjusted				Adjusted		
	OR	95% CI	*P* value		OR	95% CI	*P* value
Age (y)	1.010	1.001-1.020	0.0350		1.010	1.001-1.020	0.0326
Sex (female vs male)	1.356	1.031-1.784	0.0293		1.375	1.044-1.811	0.0235
Renal dysfunction	1.555	1.004-2.408	0.0480		1.553	1.001-2.409	0.0497

PPCs, Postoperative pulmonary complications; OR, Odds ratio; CI, Confidence interval
The Hosmer–Lemeshow goodness-of-fit test; *P*=0.6703
Area under the ROC curve; C=0.6670

Table 3: Outcome, LOS, and other characteristics of the patients who underwent cardiac surgery in RHC between September 2016 and March 2017

Characteristic	All Patients (N=918)	PPCs (n=537)	Non-PPCs (n=381)	*P* value
MV time (min)	612.95 ± 381.07	626.85 ± 397.43	593.36 ± 356.32	0.182
ICU LOS (d)	3.58 ± 1.69	3.73 ± 2.05	3.37 ± 0.93	< 0.001
Hospital LOS (d)	16.53 ± 8.17	16.98 ± 8.40	15.90 ± 7.80	0.047
Death	23 (2.5)	18 (3.4)	5 (1.3)	0.051

Data are presented as mean ± SD or n (%).
RHC, Rajaie Cardiovascular Medical and Research Center; MV, Mechanical ventilation; LOS, Length of stay; ICU, Intensive care unit; FC, Function class

DISCUSSION

PPCs are common after cardiac surgery, and as is shown in Table 3, they contribute significantly to increased morbidity, LOS in the ICU and hospital, intubation time, and mortality. In comparison with postoperative cardiac complications, PPCs are also associated with more deaths. [4] Depending on the time of their occurrence, PPCs may vary, from arterial hypoxemia, atelectasis, diaphragm dysfunction, or paralysis to pulmonary edema/ARDS, pneumonia, and pleural effusion. [2,5]
For all the published studies in this field, there is still a need for re-evaluation given the advances in surgical techniques and equipment.
The first objective of the current study was to determine the incidence of PPCs after cardiac surgery in adults in our tertiary referral cardiac center. The incidence rate of

major PPCs in patients undergoing open-heart surgery has been reported to range from 5% to as high as 80%, with variations attributed to preoperative and intraoperative risk factors. [2-6] Some studies have reported a lower incidence rate of PPCs, ranging from 3% to 16% following CABG and 5% to 7% following cardiac valve surgery. [3] In our study, the cumulative occurrence rate of PPCs was 58.5% in all types of heart surgeries. The most common PPCs noted in our patients were pleural effusion (32%), atelectasis (24.2%), pneumonia (7.4%), diaphragm dysfunction or paralysis (7.3%), and pulmonary edema/ARDS (7%).

The rate of PPCs in our investigation is high in comparison with some studies, which may be due to different definitions and criteria employed to define complications. In our previous study on patients with valve surgery, we found a PPC rate of 50% among 180 patients. [2] The present investigation is a prospective study where all PPCs were evaluated by an expert pulmonologist. We included all amounts of effusion detectable via any procedure, from simple radiography to sonography and CT scanning. Usually smaller amounts of effusion and plate atelectasis are considered to be normal and, as such, they may not be reported in retrospective studies. The use of positive end-expiratory pressure (PEEP= 7–8 cmH_2O) during the postoperative period of mechanical ventilation and early mobilization may be another reason for the lower incidence rate of atelectasis in some reports. [5] Our patients had a PEEP of 5 cmH_2O at the time of intubation, and we also used incentive spirometers postoperatively to prevent atelectasis in all the patients.

The incidence of postoperative pneumonia in the present study was 7.4%, which is lower than that reported in another similar study. [3] Our patients underwent more sophisticated preoperative evaluations, and all of them received prophylactic antibiotics. The threshold for antibiotic commencement is very low in our center. All the aforementioned factors may have exerted some influence on the lower rate of pneumonia diagnosis in our patients.

Chiming in with what we reported in another study, [2] in the present investigation, we also had in-hospital mortality in 23 adult patients, representing a hospital mortality rate of 2.5%. Although the death rate was higher in the PPC group than in the non-PPC group, the difference did not reach the significance level (OR, 2.608; 95% CI, 0.960 to 7.087; P=0.051). On the other hand, the mean hospital LOS was significantly longer in our patients with PPCs than in our non-PPC group (16.98±8.40 d vs 15.90±7.80 d; P=0.047). These findings are complementary to other studies and suggest the importance of PPCs vis-à-vis the hospital LOS and mortality of patients.

The second major objective of this study was to determine the factors that might predict the probability of the occurrence of PPCs in patients undergoing open-heart surgery. To evaluate this objective, we compared different types of perioperative factors to determine their association with PPCs and find out the independent risk factors. We hypothesized that some of these factors might exert more influence on the occurrence of PPCs and might assist in finding patients with a higher probability of pulmonary complications and death. As is shown in Table 1, among all the laboratory and clinical findings of our patients, age, sex, smoking, a history of chronic renal failure, and eGFR had statistical associations with the occurrence of all types of PPCs. The prevalence of PPCs among our patients with other factors such as a history of opium smoking or oral opium use, a history of home bakery, diabetes mellitus, higher uric acid, and a history of nocturnal suffocation was higher but not statistically significant. It was surprising that those with a history of opium addiction and the current opium users were less likely to develop PPCs. These findings may be explained by the possibility of the replacement of narcotics in the perioperative period and better pain relief in these patients or other unknown protective effects of opium.

In the current study, we also investigated other perioperative clinical characteristics of patients that were associated with PPCs. In several studies, advanced age, excess weight (the body mass index), smoking, high pulmonary artery pressure (PAP), diabetes mellitus, abnormal results of pulmonary function tests, chronic obstructive pulmonary disease (COPD), and emergency surgery consistently were identified as risk factors for PPCs after cardiac surgeries. [6-10] The most frequently identified respiratory risk factor for PPCs has been COPD, with a rate of postoperative complications that varies from 26% to 78% in several studies. [3, 7] There was an association between PPCs and obstructive patterns of spirometry in our study; nonetheless, it was not statistically significant, which is in line with other studies. [7,8] All our patients with obstructive patterns on spirometry were on bronchodilators as they had been before and received bronchodilators with nebulizers during intubation and early hours and days after extubation; moreover, they received more treatment if they experienced acute exacerbation in their respiratory symptoms.

In our study, the incidence rate of PPCs among patients with diabetes mellitus was higher, but it was not statistically significant. Silva et al reported similar findings in patients with diabetes. [7] We found no notable relationships between the body mass index and PPCs. A high PAP as estimated by echocardiography before any cardiac procedure is associated with increased morbidity and mortality. The prevalence of pulmonary hypertension in cardiac surgery patients increases in parallel with the severity of the disease. [11] In our findings, a higher level of systolic PAP was not associated with increased complications after surgery.

There were no notable changes in the percent predicted amounts of FEV1 and FVC and also the FEV1/FVC percent predicted in those with and without complications, which may lead to the conclusion that spirometry values may have no prediction power if regarded as percent predicted or even absolute values. Despite the clinically greater mean values of the intraoperative measures of the skin-to-skin time, pump time, and clamp time, none of them was statistically significant. We also found no statistically significant changes between those who received blood products of any type and those who did not, albeit those who received blood transfusion showed higher pulmonary complications.

To find out the independent risk factors for PPCs, we examined a multivariable backward logistic regression model. We entered the variables with a P value of less than 0.20 obtained via the univariable analysis (Table 1) into the model and found that of all the studied clinical and paraclinical factors, age, sex, and renal dysfunction remained as the independent risk factors that might influence PPCs. Among all the postoperative patients, women accounted for 40.4% of the patients with PPCs, whereas men comprised 59.6% of the patients with PPCs (P= 0.029). The higher incidence rate of complications in female patients may be due to the difference in the types of surgery in female patients. CABG was more common among postoperative male patients, while valvular heart surgery was more common among postoperative female patients. If we compare patients based on the type of surgery, there was no difference between the sexes, which is concordant with the findings of our previous study on patients with valve surgery. [2]

A rise in mortality in tandem with increased age (especially in those over 65 years) has been previously reported in patients with no other pulmonary risk factors. [12,13] In the current study, we found that age was an independent risk factor for PPCs. Mortasawi et al reported that age could be an important predictor of some major complications after cardiac surgery. [10] Another report showed that increased age was directly related to an increase in major complications; hence, patients aged above 50 years were more prone to major pulmonary complications, especially infectious complications. [9] Our study also is supportive of previous studies insofar as we found increased PPCs in alliance with increased age.

Renal failure is a well-known risk factor in all kinds of surgery and, thus, warrants special focus. A good indicator of renal function is probably eGFR. The morbidity and mortality rates of patients on hemodialysis who underwent abdominal surgery for gastrointestinal diseases were high in a previous investigation. [14] Nevertheless, patients with well-controlled chronic renal failure have good outcomes. Postoperative acute kidney injury, a common complication after cardiac surgery, remains an important adverse event in association with postoperative complications, longer hospital LOS, higher cost, and increased mortality. Severe acute kidney injury, which is usually combined with multiple-organ dysfunction syndrome; low cardiac output; endotoxemia; hypervolemia; hyperkalemia; and acidosis requiring renal replacement therapy have negative impacts on respiratory function and cause prolonged ventilation support or reintubation, increasing the incidence of PPCs. [3] We evaluated eGFR and creatinine for this purpose and found an association with chronic renal dysfunction and PPCs in our patients (Table 2).

Generally speaking, PPCs lead to increased hospital LOS and also in-hospital mortality. In this study, PPCs resulted in an increased risk of in-hospital death. Still, further larger-scale multicenter studies are required to define the exact effect.

The main limitation of the present study is the lack of control probably on patient selection, surgery, and anesthesia by different surgeons and anesthesiologists, as well as on postoperative care by different nurses and finally intraoperative data collection. All of these limitations originate from the observational nature of the study, and these contributing factors may limit the generalization of its results.

CONCLUSIONS

The cumulative incidence rate of PPCs was 58.5%, with a mortality rate of 3.4% in our center. Additionally, the overall mortality rate in the entire study population was 2.5%. The independent risk factors associated with PPCs in our study were age, sex, and renal failure. In this study, PPCs after cardiac surgery led to prolonged LOS in the ICU and hospital, lengthened intubation time, and increased mortality.

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Conflict of Interest: Hereby, we disclose that there were no conflicts of interest influencing the conduct of this study and that all expenses were covered by Rajaie Cardiovascular Medical and Research Center, affiliated with Iran University of Medical Sciences.

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