

Investigation of the Frequency and Risk Factors of Pulmonary Complications Following Cardiac Surgery in the Hospital

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Abstract

Objectives: The purpose of this study was to determine the frequency of pulmonary complications after heart surgery and to assess the pre-operative, intra-operative and post-operative risk factors.

Methods: This was a descriptive and analytical study that was conducted on 244 patients who underwent various cardiac surgeries from December 2021 to May 2022 in Shefa Kerman Hospital. This descriptive/analytical study on patients undergoing heart surgery at Shafa Hospital, Kerman, Iran, from December 2021 to May 2022. Pulmonary complications included atelectasis pneumonia, pleural effusion, long-term mechanical ventilation, and respiratory failure. The pre-operative, intra-operative and post-operative risk factors were investigated in the present study. SPSS software was used to analyze the data. Logistic regression analysis was employed to determine the relationship between risk factors and the incidence of lung complications.

Results: In the present study, 55 patients (22.5%) had pulmonary complications, followed by prolonged mechanical ventilation (13.1%), pneumonia (11.5%), respiratory failure (4.1%), pleural effusion (11.1%) and atelectasis (6.1%). Pulmonary complications after heart surgery were associated with days of ICU stay, post-operative stroke, post-operative acute kidney injury, emergency surgery, FFP injection, high drainage rate, and mitral valve replacement surgery (all $P < 0.001$). 4% of patients died after surgery, which was statistically related to pulmonary complications ($P < 0.0001$). The results of multivariable logistic regression test showed that FFP injection, type of heart surgery, hypertension, ICU stay days are capable of predicting pulmonary complications after heart surgery.

Conclusion: Mortality was found to be higher in patients with pulmonary complications. Based on the results of the regression analysis, FFP injection, type of surgery, history of hypertension and length of ICU stay were independent risk factors of pulmonary complications.

Key words: Pulmonary complications, cardiovascular surgery, risk factors, Fresh frozen plasma

Introduction

Cardiac surgery is a high-risk intervention that requires specialized teams to manage patients in the pre- and post-operative care. Pulmonary complications include pneumonia with mechanical ventilation for more than 24 hours, respiratory failure, pleural effusion, atelectasis, pneumothorax, bronchospasm and aspiration pneumonitis, acute respiratory distress syndrome, and pulmonary embolism, which increases the length of hospital stay and treatment costs.¹

Heart surgery is usually performed by cardiopulmonary bypass. In this technique, the pumping action of the heart and the gas exchange of the lungs are temporarily replaced by a special mechanical device called an oxygenator pump, which is connected to the vascular system. Cardiopulmonary bypass exposes the blood to artificial substances that lead to the production and secretion of toxins and the activation of the vascular reaction. In addition, the activation of neutrophils and their migration to the pulmonary circulation causes deep endothelial, epithelial, and interstitial lung damage, which is associated with increased capillary permeability, decreased lung capacity, and gas exchange disorders.^{2,3} Abnormalities in gas exchange and changes in lung mechanical function cause pulmonary complications after heart surgery. In recent studies, changes in muscle and chest wall function due to median sternotomy, systemic inflammatory response syndrome with cardiopulmonary bypass, phrenic nerve injury due to cold saline injection in the pericardial cavity during cardiac arrest, and

dilatation associated alveolar edema, and an increase in left ventricular pressure in the pulmonary vessels has been stated as the main causes of this complication.^{4,5}

The reported frequency of pulmonary complications after cardiac surgery varies from 6 to 70% depending on the criteria used to define pulmonary complications.⁶ The incidence of pulmonary complications in major surgeries varies from 1 to 23%.⁷ Identifying the risk factors of susceptible patients is helpful in preventing and eliminating complications. Previous studies reported a combination of preoperative and postoperative risk factors. Despite many advances in intraoperative care, postoperative pulmonary complications remain the main cause of disability and death after cardiac surgery in adults.^{8,9}

Very few studies have focused on intra- and post-operative risk factors responsible for pulmonary complications in patients undergoing cardiac surgery using cardiopulmonary bypass.^{10,11}

Ventilation with a flow volume of 4–6 cc/kg during surgery was associated with a decrease in pulmonary complications.¹² It has been reported that age over 60 years, prolongation of surgery time, preoperative pulmonary blood pressure and intraoperative phrenic nerve damage were risk factors for pulmonary complications.⁶

Determining the factors affecting the rate of pulmonary complications can be beneficial in order to reduce these risk factors and timely treatment of more common pulmonary complications in patients after heart surgery. If risk factors are found, comprehensive and complete treatment of these factors

can be effective in improving the clinical course of patients who underwent heart surgery.

In Iran, there is a lack of studies on pulmonary complications after heart surgery.^{13,14} Considering the large number of heart surgeries in Iran and the high global prevalence of postoperative pulmonary complications, it is necessary to determine the prevalence of this complication and its related factors in Iran. The current study aimed to investigate the frequency and risk factors of pulmonary complications following cardiac surgery in Shafa Hospital between 2021 and 2022.

Materials and Methods

This is a descriptive/analytical cross-sectional study approved by the ethics committee of Kerman University of Medical Sciences (IR.KMU.AH.REC.1401.104).

The research population included all patients who underwent heart surgery (coronary artery grafting, heart valve replacement, atrial septum repair, and ventricular septal defect repair) at Shafa Hospital, Kerman, Iran, from December 2021 to May 2022.

The research population included all patients who underwent heart surgery (coronary artery grafting, heart valve replacement, atrial septum repair, and ventricular septal defect repair) at Shafa Kerman Hospital from December 2021 to May 2022. Patients who had surgery for congenital heart disease and incomplete medical records were excluded from the study.

The data was extracted from the patient files through a researcher-made form including demographic information and medical information.

Collected data includes the variables of age, sex, smoking, opioid use, body mass index, ejection fraction, type of surgery, duration of surgery, type of pulmonary complication, use of cardiopulmonary pump during surgery. Surgery, duration of cardiopulmonary pump, duration of mechanical ventilation, acute kidney injury after surgery, hemoglobin level before surgery, co-morbidity (diabetes, hypertension), duration of hospitalization in intensive care unit (ICU), transfusion of blood or blood products, type of surgical urgency, postoperative drainage and mortality.

Pulmonary complications investigated included: pleural effusion, which was investigated and recorded by lung ultrasound and x-ray), pneumonia (fever, purulent sputum, test findings, lung x-ray and confirmed by infectious consultation), atelectasis (confirmed by lung x-ray and ultrasound), prolonged mechanical ventilation (more than 24 hours) and acute respiratory distress syndrome (ARDS).

Statistical Analysis

Descriptive data were presented using mean, standard deviation, frequency and percentage in the form of tables and graphs. The Kolmogorov Smirnov test was used to check the normality of the data. T-test was used to compare the mean of two groups for normal data. Mann Whitney U test for non-normally distributed data and Chi square test was used to analyze qualitative data. Logistic regression analysis (Backward: LR) was used to investigate the simultaneous effect of demographic and medical variables with postoperative pulmonary complications. The first group was considered as the reference group. SPSS software version 24 was used for data analysis. A significance level of less than 0.05 was considered.

Results

244 patients with a mean age of 59 ± 12 (15–82 years) participated in this study, consisting of 167 (68%) men and 77 (32%) women. The average height and weight of the patients were 168 ± 9 and 68 ± 13 , respectively. The average BMI in these people was 24 ± 4 (range 14–37). 50% of patients used opium and 10% smoked. Of these patients, 36% had diabetes, 68% had hypertension, and 5% had chronic kidney disease.

The mean preoperative hemoglobin in the patients was 14 ± 2 . The average ejection fraction in patients was 44 ± 10 . The average ejection fraction in patients before surgery was determined to be 44 ± 10 .

6% of patients underwent emergency surgery and 88% underwent elective surgery. The average time of surgery was 4 ± 0.8 hours (range 2–8 hours). 49% of patients used cardiopulmonary pump with an average duration of 37 ± 32 minutes.

According to the type of surgery, 87% of patients underwent open heart surgery, followed by mitral valve replacement (8%), aortic valve replacement (6%), septal defect surgery (3%), and other surgeries (3%). After surgery, 55 patients (22.5%) had pulmonary complications, followed by prolonged mechanical ventilation (13.1%), pneumonia (11.5%), respiratory failure (4.1%), pleural effusion (11.1%) and atelectasis (6.1%).

The duration of the intensive care unit (ICU) stay after the operation was 5 ± 3 days. The average duration of mechanical ventilation in patients was also determined to be 22 ± 31 (range 4.5–264 hours) hours.

During or after FFP operation, 17% of PLT and 51% of P.C were injected for 20% of patients. The amount of drainage after surgery was found to be less than one liter for 85% of patients and more than one liter for 15%. 2.5% of patients had a stroke after surgery and 17.6% had acute kidney failure. Finally, 4% of patients died after surgery.

No significant difference was found in terms of the gender in two groups with pulmonary complications after cardiac surgery and without pulmonary complications after cardiac surgery.

No significant difference was observed between on-pump and off-pump patients in two groups with pulmonary complications after heart surgery and without pulmonary complications after heart surgery.

A significant difference was found in terms of the type of urgency in two groups after heart surgery. Patients who underwent emergency surgery had more pulmonary complications after heart surgery.

A statistically significant difference was also revealed in terms of drainage in two groups after heart surgery. Patients who had more than one liter of drainage on the first day had more pulmonary complications after heart surgery.

A significant difference was observed in terms of post op CVA in two groups after heart surgery. All patients who had a stroke had pulmonary complications after heart surgery.

A statistically significant difference was found in terms of death in patients in two groups after heart surgery, where patients who died showed more pulmonary complications after heart surgery.

A significant difference was also seen in terms of acute kidney injury in patients of two groups after heart surgery. The frequency of pulmonary complications was higher in patients with acute kidney injury.

Table 1. Descriptive statistics

	<i>N</i>	Minimum	Maximum	Mean	Std. deviation
Age in years	243	15	82	58.75	11.699
Weight in kg	244	2.00	120.00	68.3975	13.26509
Height in cm	244	147.00	198.00	168.1844	8.55885
BMI	205	14.03	36.63	24.0432	3.92621
Ejection fraction in percent	238	20.00	65.00	44.0126	10.19700
Surgery duration in minutes	244	140.00	465.00	251.6189	47.83311
Pump_time in minutes	244	.00	199.00	32.1352	36.59693
Days of ICU admission	244	1.00	24.00	4.9508	3.22631
Mechanical ventilation hours	244	4.50	264.00	22.0266	30.58241
Pre op Hb	244	9.1	22.7	14.201	2.1269
Valid N (listwise)	199				

No significant difference was observed in patients of two groups in terms of drug use, smoking, blood pressure, diabetes and chronic kidney disease.

A significant difference was observed in terms of mitral valve replacement in the two groups of patients after heart surgery. The frequency of pulmonary complications was higher in patients who had mitral valve replacement.

A significant difference was observed in terms of other surgeries in patients of two groups. The frequency of pulmonary complications was higher in patients who had other surgeries.

In terms of FFP injection, a significant difference was observed in two groups. The frequency of pulmonary complications was higher in patients who received FFP injection.

There was no statistically significant difference in the mean age of patients in the two groups ($P = 0.374$)

No statistically significant difference was found in the average duration of surgery in the two groups of patients ($P = 0.735$)

There was a statistically significant difference in the average days of the ICU stay in the two groups of patients ($P < 0.0001$). The average days of ICU stay was found to be higher in the group of patients with pulmonary complications after heart surgery ($P < 0.0001$).

There was no statistically significant difference between the two groups of patients in the mean preoperative hemoglobin ($P = 0.603$).

The average time of being on the pump in the group of patients with pulmonary complications was higher than the patients without pulmonary complications, but this difference was not found to be statistically significant ($P = 0.101$).

The results of multivariable logistic regression test demonstrated that FFP injection, type of heart surgery, blood pressure, and number of days of the ICU stay can be capable of predicting pulmonary complications after heart surgery. People who had aortic valve replacement surgery are 91.7 times more likely to have pulmonary complications after heart surgery. People who had mitral valve replacement surgery are 73 times more likely to have pulmonary complications after heart surgery. Patients who had septal defect surgery are 128 times more likely to have pulmonary complications after heart surgery.

Patients with open heart surgery have 36.8 times more pulmonary complications after heart surgery. Every day ICU stay was capable of increasing the chance of pulmonary complications by 1.72 times. People who had high blood pressure are 4.6 times more likely to have pulmonary complications after heart surgery. Patients who received FFP injections were 4.6 times more likely to have pulmonary complications after heart surgery.

Discussion

The present study was conducted with the aim of investigating the frequency and risk factors of pulmonary complications following heart surgery in Shafa Hospital from December 2021 to May 2022. 244 patients who underwent heart surgery during a period of 6 months were included in the study. In our study, there was no relationship between pulmonary complications and demographic characteristics, including average age, sex, and body mass index.

The results of our study showed an incidence of 22.5% for pulmonary complications after heart surgery. Pulmonary complications after heart surgery were related to type of surgery (mitral valve replacement surgery, other heart surgeries), history of hypertension, prolonged stay in ICU, urgency of heart surgery, post-operative acute kidney injury, post-operative stroke, FFP injection and high drainage rate.

Mortality was significantly higher in patients with pulmonary complications. Regarding the regression analysis of plasma injection, type of surgery, history of hypertension and length of stay in ICU were independent risk factors for developing pulmonary complications.

One of the positive points of our study was the comprehensive review of pre-operative, intra-operative and post-operative risk factors in order to determine the frequency and risk factors influencing the development of pulmonary complications. Regarding the retrospective nature of the study, it was not possible to investigate the thickness of the diaphragm and possible paralysis in pulmonary complications.

The most common pulmonary complications in patients were long-term mechanical ventilation (more than 24 hours, 13.1%) and pneumonia (11.5%). Considering that infection is an important factor of morbidity and mortality around

Table 2. Frequency of pulmonary complications in heart surgery patients according to demographic and clinical characteristics

		Total		Pulmonary complication			P-value
		Frequency	Percent	Yes	No		
Sex	Male	167	68.4	Frequency	39	128	0.655
				Percent	23.4%	76.6%	
	Female	77	31.6	Frequency	16	61	
				Percent	20.8%	79.2%	
Pump	Off	125	51.2	Frequency	26	99	0.505
				Percent	20.8%	79.2%	
	On	119	48.8	Frequency	29	90	
				Percent	24.4%	75.6%	
Urgent type of surgery	Emergency	14	5.7	Frequency	11	6	$P < 0.0001$
				Percent	64.7%	35.3%	
	Elective	216	88.5	Frequency	44	183	
				Percent	19.4%	80.6%	
Drainage	Below 1lit	207	84.8	Frequency	42	165	0.047
				Percent	20.3%	79.7%	
	Over 1lit	37	15.2	Frequency	13	24	
				Percent	35.1%	64.9%	
Post op CVA	No	238	97.5	Frequency	49	189	$P < 0.0001$
				Percent	20.6%	79.4%	
	Yes	6	2.5	Frequency	6	0	
				Percent	100.0%	0.0%	
Death	No	234	95.9	Frequency	48	186	$P < 0.0001$
				Percent	20.5%	79.5%	
	Yes	10	4.1	Frequency	7	3	
				Percent	70.0%	30.0%	
Acute kidney injury	No	201	82.4	Frequency	37	164	0.001
				Percent	18.4%	81.6%	
	Yes	43	17.6	Frequency	18	25	
				Percent	41.9%	58.1%	

Table 3. Frequency of pulmonary complications in heart surgery patients based on underlying diseases, type of heart surgery and transfusion of blood and blood products

			Total		Pulmonary complication		
			Frequency	Percent	No	Yes	
Underlying diseases	Opioid addiction	No	123	50.4	Frequency	101	22
					Percent	82.1%	17.9%
		Yes	121	49.6	Frequency	88	33
					Percent	72.7%	27.3%
	Smoking	No	219	89.8	Frequency	170	49
					Percent	77.6%	22.4%
		Yes	24	9.8	Frequency	19	5
					Percent	79.2%	20.8%
	Unknown	.4	.4	Frequency			

(continued)

Table 3. Frequency of pulmonary complications in heart surgery patients based on underlying diseases, type of heart surgery and transfusion of blood and blood products—Continued

			Total			Pulmonary complication	
			Frequency	Percent		No	Yes
Type of cardiac surgery	Diabetes mellitus	No	157	64.3	Percent	125	32
					Frequency	79.6%	20.4%
		Yes	87	35.7	Percent	64	23
					Frequency	73.6%	26.4%
	Hypertension	No	79	32.4	Percent	65	14
					Frequency	82.3%	17.7%
		Yes	165	67.6	Percent	124	41
					Frequency	75.2%	24.8%
	Chronic kidney disease	No	230	94.3	Percent	180	50
					Frequency	78.3%	21.7%
		Yes	12	4.9	Percent	7	5
					Frequency	58.3%	41.7%
	Unknown	2	.8	Percent			
Type of cardiac surgery	Aortic valve replacement	No	230	94.3	Frequency	180	50
					Percent	78.3%	21.7%
		Yes	14	5.7	Frequency	9	5
					Percent	64.3%	35.7%
	Mitral valve replacement	No	225	92.2	Frequency	178	47
					Percent	79.1%	20.9%
		Yes	19	7.8	Frequency	11	8
					Percent	57.9%	42.1%
	septal defect	No	236	96.7	Frequency	182	54
					Percent	77.1%	22.9%
		Yes	8	3.3	Frequency	7	1
					Percent	87.5%	12.5%
Cardiac arterial bypass graft	No	32	13.1	Frequency	25	7	
				Percent	78.1%	21.9%	
	Yes	212	86.9	Frequency	164	48	
				Percent	77.4%	22.6%	
other	No	237	97.1	Frequency	186	51	
				Percent	78.5%	21.5%	
	Yes	7	2.8	Frequency	3	4	
				Percent	42.9%	57.1%	
Transfusion of blood and blood products	FFP	No	196	80.3	Frequency	163	33
					Percent	83.2%	16.8%
		Yes	48	19.7	Frequency	26	22
					Percent	54.2%	45.8%
	PLT	No	202	82.8	Frequency	159	43
					Percent	78.7%	21.3%
		Yes	42	17.2	Frequency	30	12
					Percent	71.4%	28.6%
	P.C	No	120	49.2	Frequency	93	27
					Percent	77.5%	22.5%
		Yes	124	50.8	Frequency	96	28
					Percent	77.4%	22.6%

Table 4 Frequency of pulmonary complications in patients

Variables		Frequency	Percent
Pulmonary complication	No	189	77.5
	Yes	55	22.5
Pneumonia	No	216	88.5
	Yes	28	11.5
Respiratory failure	No	234	95.9
	Yes	10	4.1
Pleural effusion	No	217	88.9
	Yes	27	11.1
Atelectasis	No	229	93.9
	Yes	15	6.1
Prolonged mechanical ventilation	No	212	86.9
	Yes	32	13.1

surgery, it is necessary to examine and identify patients at risk for faster control and treatment.

The occurrence of pulmonary complications in studies has been between 3 and 50% and its occurrence is the result of pre-operative, intra-operative and post-operative risk factors.

Older age, genetics, diabetes, obesity, smoking, chronic lung disease, and emergency surgery have been identified as preoperative risk factors in studies. In our study, emergency surgery and hypertension were risk factors, while other comorbidities were not associated with increased risk, probably owing to the smaller sample size.

In our study, one of the risk factors affecting the increase of pulmonary complications during surgery was the type of surgery, i.e., non-coronary and heart valve surgeries.

In Sadeghi's study, patients with heart valve surgery had higher complications and mortality because a large number of these patients suffer from obstructive and restrictive lung disease, which may be due to cardiomegaly, pleural effusion,

Table 5. Comparison of the mean of quantitative variables in two groups of patients with pulmonary complications and without pulmonary complications after heart surgery

Variables	Pulmonary complication	N	Mean	Std. deviation	Std. error mean	P-value
Age in years	No	189	58.39	11.945	.869	.374
	Yes	54	60.00	10.807	1.471	
Surgery duration in minutes	No	189	251.0582	45.20570	3.28823	.735
	Yes	55	253.5455	56.36088	7.59970	
Days of ICU admission	No	189	4.1111	1.67056	.12152	$P < 0.0001$
	Yes	55	7.8364	5.11629	.68988	
Pre op Hb	No	189	14.239	2.1108	.1535	.603
	Yes	55	14.069	2.1958	.2961	
Pump_time in minutes	No	189	29.5185	32.98204	2.39909	0.101
	Yes	55	41.1273	46.18965	6.22821	

Table 6. The results of multivariate logistic regression

	B	S.E.	Exp(B)	95% C.I. for EXP(B)		P-value
				Lower	Upper	
Gender (1)	-.815	.793	.443	.094	.304	.304
Age in years	-.031	.028	.969	.917	.270	.270
BMI	.050	.069	1.052	.918	.466	.466
Aortic valve replacement (1)	4.519	1.504	91.725	4.813	.003	.003
Mitral valve replacement (1)	4.295	1.755	73.337	2.351	.014	.014
Septal defect (1)	4.857	2.061	128.574	2.265	.018	.018
Coronary arterial bypass (1)	3.606	1.660	36.803	1.423	.030	.030
Surgery duration in minutes	-.002	.008	.998	.982	.752	.752
Pump (1)	-2.136	1.334	.118	.009	.109	.109
Pump_time in minutes	.021	.020	1.021	.982	.298	.298
Opioid addiction (1)	.923	.518	2.516	.911	.075	.075
Smoking (1)	-.010	.951	.990	.153	.991	.991
Diabetes mellitus (1)	.429	.610	1.536	.465	.482	.482
Hypertension (1)	1.540	.690	4.665	1.206	.026	.026

(Continued)

Table 6. The results of multivariate logistic regression—Continued

	B	S.E.	Exp(B)	95% C.I. for EXP(B)		P-value
				Lower	Upper	
Chronic kidney disease (1)	-2.842	2.312	.058	.001	.219	.219
Days of ICU admission	.545	.126	1.724	1.346	.000	.000
FFP (1)	1.539	.591	4.658	1.463	.009	.009
PLT (1)	-1.676	.797	.187	.039	.036	.036
PC (1)	-.529	.665	.589	.160	.427	.427
Acute kidney injury (1)	.041	.781	1.042	.225	.958	.958
Urgent type of surgery (1)	-.690	.946	.502	.079	.466	.466
Drainage (1)	.290	.762	1.336	.300	.704	.704
Constant	-14.449	3.152	.000	.000	.000	.000

peribronchial and pericapillary fibrosis during the period of pulmonary congestion.¹⁴

In our study, Fresh frozen plasma injection was an independent risk factor for pulmonary complications. It was stated by Gupta et al. that intraoperative blood transfusion was significantly higher in patients with pulmonary complications after surgery.¹⁵ While the results of the study by Mathis and his colleagues showed a significant relationship between the transfusions of various blood products and pulmonary complications after heart surgery.¹² Following the infusion of blood products, especially plasma and platelets, there is a possibility of complications such as transfusion-related acute lung injury (TRALI), transfusion-related circulatory overload (TACO) and increased risk of infection transmission.^{16,17}

Serani et al. also showed that plasma transfusion in sick patients was associated with an increased risk of infections.¹⁸ Bochicchio's study showed an increased risk of ventilator-associated pneumonia in trauma patients with transfusion of blood products.¹⁹ According to the results of our study, plasma injection was introduced as a risk factor for causing postoperative pulmonary complications. Transfusion of plasma and blood products is recommended to be based on the indication,

if necessary. According to Desborough's review study, the prophylactic administration of Fresh frozen plasma for patients undergoing cardiovascular surgery is not approved in the absence of coagulopathy, and more research is needed for other outcomes including 30-day mortality due to the bias in the studies and their low quality.²⁰

In the present study, acute kidney failure and longer length of ICU stay were associated with increased pulmonary complications, which was consistent with other studies.²¹

The mortality rate in patients with pulmonary complications was significantly higher, which was similar to other studies.^{6,22}

Pulmonary complications after heart surgery can be prevented by teaching the prevention and management of these risk factors to the health department staff and determining specific protocols. Further longitudinal and multicenter studies are needed to investigate the risk factors of pulmonary complications after heart surgery.

Conflict of Interest

None. ■

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