

# Evaluation of Pulmonary Complications in Patients With Valvular Heart Surgery: Clinical and Laboratory Significances

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## Abstract

**Background:** Pulmonary complications following cardiac valvular surgery are common and contribute to increased rate of hospital stay, morbidity and mortality. This study was conducted to determine the incidence of pulmonary complications after cardiac valvular surgery and to investigate perioperative clinical factors for postoperative pulmonary complications at a tertiary university hospital.

**Methods:** Overall, 180 consecutive adult patients (> 18 years), who underwent nonemergency aortic, mitral, pulmonary or tricuspid valvular surgery were enrolled. Before surgery, lung function and gas exchange were measured. Complete history taking, vital signs and clinical examination was done and Chest X-Ray, Electrocardiogram (ECG), echocardiography, blood gas analysis, and complete blood tests were obtained and patients were followed throughout surgery and after that, till discharge from the hospital for detection of respiratory complications. The relevant pre-, intra-, and post-operative data of all patients were investigated and analyzed.

**Results:** The cumulative incidence of pulmonary complications was 50 (90 of 180) with a mortality rate of 6.6% (6 of 90) and the overall mortality among all patients was 3.3% (6 of 180). Type of valvular surgery was significantly associated with postoperative pulmonary complications (POPC). With regards to cardiac risk factors, Hypertension (HTN) and smoking had a significant relationship with POPC ( $P < 0.0001$ ,  $P = 0.003$  respectively). Bivariate analyses showed that older patients were more susceptible to POPC ( $P < 0.0001$ ). There was no significant difference in POPC ( $P = 0.55$ ) between males and females. Prolongation of operation time ( $P = 0.03$ ), cross clamp time ( $P = 0.04$ ) and pump time ( $P < 0.0001$ ) were associated with POPC. There was a significant relationship between PaO<sub>2</sub> in AIR and 100% FIO<sub>2</sub>, and POPC ( $P = 0.02$ ,  $P = 0.007$ , respectively). There was a significant relationship between death and POPC ( $P = 0.01$ ).

**Conclusions:** Type of valvular surgery, hypertension, smoking, older age, pump time, operation time, cross clamp time and Pao<sub>2</sub> in air and 100% O<sub>2</sub> were the most important factors associated with postoperative pulmonary complications.

**Keywords:** Postoperative Pulmonary Complications, Cardiac Valvular Surgery, Perioperative Risk Factors

## 1. Background

Pulmonary complications are common following heart surgeries and replacement of diseased valves is often associated with more significant morbidity, prolonged hospital stay and mortality (1, 2).

The various components of the respiratory system including airways, lungs, chest wall, intercostal muscles, diaphragm and neural pathways may be damaged by a variety of processes of cardiac surgery and affect the function of the pulmonary system. Additionally, changes in systemic and pulmonary blood pressure and allergic reaction to drugs and membrane may increase capillary permeability leading to alveolar edema while mechanical problems may occur following phrenic nerve damage (3).

Atelectasis and pleural effusions, pulmonary embolism, Pneumonia, diaphragm paralysis and acute respiratory distress syndrome (ARDS) are the most important and morbid pulmonary complications after cardiac

surgery (1).

The factors affecting the development of postoperative pulmonary complications (POPC) are related to the prior health status of the patient, the effects of anesthesia and procedural events. Because of these wide and varied factors, incidence rates of pulmonary complications after heart surgery vary dramatically (4).

The achievement of adequate preoperative evaluation of pulmonary risk may allow reduction of such complications with appropriate measures that leads to decremented perioperative morbidity and hospital stay and costs (5).

Although pulmonary complications after surgery are frequent and important, our knowledge of the perioperative factors that increase the risk of these complications is limited.

## 2. Objectives

The aim of this study was to determine the incidence of pulmonary complications after cardiac valvular surgery and to investigate perioperative clinical and laboratory factors and pulmonary function variables that are associated with postoperative pulmonary complications in patients undergoing nonemergency cardiac valvular surgery at a tertiary university hospital.

## 3. Methods

Overall, 180 consecutive adult patients (> 18 years), who were considered for aortic, mitral or tricuspid alone or multiple valvular surgery in our cardiovascular medical and research center were followed from admission to discharge without intervention and enrolled in the study if they had valvular or non-emergency surgery.

Patients, who underwent emergency surgery, coronary artery bypass grafting (CABG) or congenital heart surgeries, were excluded. The local ethical committee approved this prospective study.

Demographic data and all patient history of comorbid diseases such as diabetes mellitus, renal failure, respiratory diseases, chronic obstructive pulmonary disease (COPD), and function class of patients were obtained from their documents or were asked directly from patients. All of them received general anesthesia and pump oxygenator during surgery, as it was routine at our hospital. All surgeries were performed via median sternotomy. Cold-blood cardioplegia was used for cardiac arrest. At the ICU, the patients were extubated when they were hemodynamically stable and able to breathe adequately. After extubating, oxygen saturation (SPO<sub>2</sub>) was maintained above 90% by supplemental oxygen and patients could leave their bed as soon as general condition and patients tubing allowed.

Before surgery, lung function and gas exchange were measured. Complete history taking, vital signs and clinical examination, chest X-Ray, pulse-oximetry, ECG, echocardiography, blood gas analysis, and complete blood test, was done to detect respiratory problems. Blood culture and special evaluation was done if the patient had complications requiring diagnostic tests or procedures.

To obtain the amount of total prevalence of complications, the frequency of all morbidity in 24, 48 and 72 hours after surgery, also after leaving the intensive care unit (ICU) and before discharge were summed. Diagnosis of complications was based on the following definitions: Atelectasis approved by CXR, or CT scan based on our radiologist or pulmonologist report. Plate atelectasis, lobar, multi-lobar atelectasis or lung or collapse considered as atelectasis.

Hospital acquired pneumonia (HAP) or ventilator associated pneumonia (VAP) diagnosis were based on presence of new pulmonary infiltrates on chest X ray or CT scan, fever, cough or sputum after operation. Leukocytosis is common after these kinds of operations and we considered hospital acquired Pneumonia in our patient if they had at least two or more of the above findings besides leukocytosis. Ventilator associated pneumonia was accepted if the patient remained intubated more than 48 hours and had criteria of pneumonia.

Diagnosis and classification of ARDS was based on Berlin definition of ARDS. Rule out of cardiac disease or valvular malfunction was always done by echocardiography or trans-esophageal echo if indicated clinically.

Diaphragm paralysis was diagnosed if significant permanent diaphragm elevation was seen on Chest X-Ray (CXR) and/or ultrasonography approved decreased or absence of diaphragm muscles contraction. Phrenic nerve conduction velocity (NCV) and diaphragm Electromyogram (EMG) were not available at our center.

Pleural effusion was diagnosed based on Chest radiography, Sonography of the pleura, echocardiography or computerized tomography (CT) scan and appreciated if it was more than 2 intercostal spaces on radiography.

We considered pulmonary emboli in our patient based on CT angiography and direct observation of clot on echocardiography.

### 3.1. Statistics

Mean, standard deviation (SD) and frequency was used for descriptive analysis. For evaluation of the distribution of data, one-sample Kolmogorov-Smirnov test was used. To evaluate the relationship between the perioperative variables and outcomes, we used the Chi-square test or Fisher's exact test for qualitative variables and the t test or Mann-whitney U test for continuous variables. Multivariate logistic regression analysis was performed in order to identify independent associations between the variables studied and presence or absence of POPC. Statistical analysis was performed with SPSS 22 for Windows (SPSS Inc., Chicago, Illinois).

## 4. Results

Overall, 180 patients (92 males and 88 females) with a mean age of  $49 \pm 15.9$  were studied. Demographic and perioperative data are shown in [Table 1](#).

### 4.1. Pulmonary Complications After Cardiac Valvular Surgery

The incidences of pulmonary complications after cardiac valvular surgery are demonstrated in [Table 2](#). There

was no patient with pulmonary embolism and pulmonary aspiration. The most common pulmonary complications were atelectasis, pleural effusion and pulmonary edema (Table 2).

The cumulative incidence of pulmonary complications was 50% (90 of 180) with a mortality rate of 6.6% (6 of 90) and the overall mortality among all patients was 3.3% (6 of 180).

#### 4.2. Perioperative Clinical Data Association With Postoperative Complications

The results of bivariate analyses are outlined in Table 3.

As seen in Table 3, type of valvular surgery was significantly associated with postoperative pulmonary complications (POPC) as patients who had AVR were more prone to POPC ( $P = 0.04$ ) and patients who had PVR had significantly less pulmonary complications after surgery ( $P = 0.009$ ). With regards to cardiac risk factors, hypertension (HTN) and cigarette smoking had a significant relationship with POPC ( $P < 0.0001$ ,  $P = 0.003$  respectively). Bivariate analyses showed that older patients were more susceptible to POPC ( $P = < 0.0001$ ). There were no significant differences between males and females regarding POPC ( $P = 0.55$ ).

Pulmonary artery pressure (PAP) was significantly higher in patients with POPC in comparison with patients without POPC ( $P = 0.003$ ).

In patients with pulmonary complications after surgery, creatinine and FBS was not significantly different in the two groups ( $P = 0.54$ ,  $P = 0.12$ , respectively). There was not significant relationship between obstructive or restrictive COPD and POPC ( $P = 0.77$ ).

Body mass index and history of previous respiratory disease had a significant relationship with POPC ( $P = 0.01$  and  $P = 0.02$  respectively) (Table 3).

With regards to operation data, operation time ( $P = 0.003$ ), cross clamp time ( $P = 0.04$ ) and pump time ( $< 0.0001$ ) were associated with POPC as in patients with POPC, they were significantly higher than patients without POPC.

Prolonged ventilation (ventilation time more than 48 hours) is associated with POPC ( $P = 0.01$ ). There was a significant association between length of hospital stay and POPC ( $P < 0.0001$ ) as patients with POPC had longer hospital stay in comparison with patients without POPC.

The ABG AIR and  $FIO_2-100$  results are shown in Table 3. There was a significant relationship between  $PO_2$  in Air ABG and  $FIO_2-100$ , and POPC ( $P = 0.02$  and  $P = 0.007$  respectively) but  $PCO_2$  in Air ABG and  $FIO_2-100$  were not significantly different in patients with POPC compared to patients without POPC ( $P = 0.41$  and  $P = 0.21$ , respectively).

All patients who died after surgery were in the POPC group. There was a significant relationship between death and POPCs ( $P = 0.01$ ).

Use of blood and blood products was compared in the two groups of patients (Table 4). The use of packed cell (PC) 24 and 72 hours after surgery were significantly higher in patients with POPC in comparison with patients without POPC ( $P < 0.05$ ). However, the use of Fresh Frozen Plasma (FFP) during surgery was significantly higher in patients with POPC ( $P = 0.02$ ), but there were no significant differences between groups regarding use of FFP postoperatively ( $P > 0.05$ ). There were no statistically significant differences between groups regarding use of Platelet (PLT) perioperatively ( $P > 0.05$ ).

According to the multivariate analysis, the variables that increased the chance of POPC were: age (OR = 1.05), BMI (OR = 3.60) and HTN (OR = 2.17) (Table 5).

## 5. Discussion

Postoperative pulmonary complications (POPC) are frequent and contribute significantly to morbidity, prolongation of hospital stay and mortality. Furthermore, POPC are more associated with death after surgery in comparison with cardiac complications (4).

Postoperative pulmonary complications depending on the time of occurrence, vary from arterial hypoxemia early after surgery, during the later course, pneumonia, and in rare cases also lead to acute lung injury (2).

The first aim of this study was to determinate the incidence of pulmonary complication after cardiac valvular surgery at a referral heart center.

The occurrence of major postoperative pulmonary complications is between 5 and 80% with variation attributed to preoperative and intra-operative risk factors (4). Some studies have reported a lower incidence rate of POPC; ranging from 3 to 16 percent following coronary artery bypass grafting and 5 to 7% following cardiac valvular surgery (2).

In our study, the incidence of postoperative pulmonary complications was 50%. This rate of complication seems to be high in comparison to other studies and we think it is dependent on range of definition of complications. We included plate atelectasis, pulmonary edema and hypoxemia as complications and also our study was on patients with valvular surgery, not all kinds of cardiac surgery. Valvular heart surgery by de novo has more complications and mortality than other kinds of cardiac surgery, especially multi valvular heart surgery, which is a common surgery at our center.

In the current study, atelectasis occurred in 12.2% (22 of 180). Al-Qubati et al. reported an incidence of 1.11% for

**Table 1.** Descriptive Data of the Patients (n = 180)

Variables	
<b>Gender, %</b>	
Male	51.1
Female	48.9
<b>Age</b>	49.96 ± 15.96
<b>Surgery duration, h</b>	4.99 ± 1.06
<b>Cross clamp time, min</b>	62.27 ± 25.02
<b>Pump time</b>	1.37 ± 0.48
<b>Type of Surgery, No. (%)</b>	
MVR	119 (66.1)
AVR	46 (25.6)
TVR	26 (14.4)
PVR	24 (13.9)
<b>History of respiratory disease</b>	
	11 (6.1)
<b>Cardiac risk factors, No. (%)</b>	
DM	27 (15)
HTN	79 (43.9)
FH	104 (57.8)
HLP	50 (29)
C/S	130 (72.2)

Abbreviations: AVR, Aortic valve repair/ reconstruction; CS, Cigar smoking; DM, Diabetes mellitus; FH, Family history; HTN, Hypertension; HLP, Hyperlipidemia; MVR, mitral valve repair/ reconstruction; PVR, Pulmonary valve repair/ reconstruction; TVR, Tricuspid valve repair/ reconstruction.

**Table 2.** Pulmonary Complications After Valve Replacement

Pulmonary Complications	No. (%)
Atelectasis	22 (12.2)
Diaphragm paralysis	8 (4.4)
Pneumonia	11 (6.1)
ARDS	3 (1.7)
Hemothorax	3 (1.7)
Pulmonary edema	25 (13.9)
Pleural effusion	70 (38.9)

Abbreviation: ARDS, acute respiratory distress syndrome.

atelectasis in their study and explained that undetectable micro-atelectasis clinically and radiographically, or the use of positive end expiratory pressure (PEEP of 7 - 8 cm H<sub>2</sub>O) during the postoperative period of mechanical ventilation, was the main reason for low incidence of atelectasis (3). Our patients had 5 cm positive end expiratory pressure at the time of intubation and we also used incentive spirometry thereafter for prevention of atelectasis immediately after surgery in all patients.

The incidence of postoperative pneumonia in the present study was 11 (6.1%), which was lower than several studies (3). This difference could be explained by presence of antibiotic prophylaxis with vancomycin and ceftriaxone in all patients, and strict pre-operation criteria for evaluation of patients. We also think that special focus of this study on patients with valvular heart diseases may explain

the difference between this study and others, which often cover all range of cardiac diseases in their study. These kinds of patients have more sophisticated pre-operation evaluations in comparison with other simple cardiac surgeries.

The second aim of this study was to investigate perioperative clinical characteristics associated with POPC. In several studies, advanced age, excess weight (BMI), smoking, high pulmonary artery pressure (PAP), diabetes mellitus, abnormal results of pulmonary function tests, COPD and emergency surgery consistently were identified as risk factors for POPC after cardiac surgeries (6).

The most frequently identified risk factor for POPC is COPD, with a rate of postoperative complications that varies from 26% to 78% (7). There was no significant association between POPC with COPD and asthma in our study

**Table 3.** Clinical Characteristics of Patients With and Without Postoperative Pulmonary Complications (POPC)

Characteristics	With POPC	Without POPC	P-Value
Age, y	54.23 ± 14.72	43.77 ± 15.51	< 0.0001
<b>Gender</b>			0.55
Male	48	44	
Female	42	46	
<b>BMI</b>	25.18 ± 3.08	23.98 ± 3.50	0.01
<b>Type of surgery, No. (%)</b>			
MVR	63 (70.0)	56 (62.2)	0.27
AVR	29 (32.2)	17 (18.9)	0.04
TVR	11 (12.2)	15 (16.7)	0.39
PVR	6 (7)	18 (20.7)	0.009
<b>Number of replaced valves, No. (%)</b>			
1	71 (81.1)	73 (78.9)	0.66
2	15 (16.7)	15 (16.7)	
3	4 (2.2)	2 (4.4)	
<b>Lung diseases, No. (%)</b>			0.77
obstructive	6 (6.7)	7 (7.8)	
restrictive	84 (93.3)	83 (92.2)	
<b>DM, No. (%)</b>	17 (18.9)	10 (11.1)	0.14
<b>HTN, No. (%)</b>	53 (58.9)	26 (28.9)	< 0.0001
<b>Smoking, No. (%)</b>	34 (37.8)	16 (17.8)	0.003
<b>Previous respiratory disease, No. (%)</b>	9 (10)	2 (2.2)	0.02
<b>SPAP</b>	39.89 ± 12.17	35.55 ± 14.16	0.003
<b>Laboratory tests</b>			
Cr	0.96 ± 0.35	0.91 ± 0.21	0.54
FBS	107.13 ± 46.33	98.67 ± 44.12	0.12
<b>Operation data</b>			
surgery for first time, No. (%)	69 (76.7)	63 (70)	0.30
Two or more surgeries, No. (%)	21 (23.3)	27 (30)	
Surgery time, h	5.20 ± 1.07	4.79 ± 0.88	0.003
Pump time, min	109.22 ± 40.52	90.70 ± 33.92	< 0.0001
Cross clamp time, min	66.78 ± 27.85	57.60 ± 20.85	0.04
Ventilation time > 48hours, No. (%)	6 (6.7)	0 (0)	0.01
<b>ABG (AIR)</b>			
PCO <sub>2</sub>	34.57 ± 6.39	33.20 ± 4.58	0.41
PO <sub>2</sub>	74.96 ± 20.78	77.30 ± 11.02	0.02
<b>ABG (FIO<sub>2</sub>-100)</b>			
PCO <sub>2</sub>	32.03 ± 5.94	30.69 ± 6.05	0.27
PO <sub>2</sub>	217.83 ± 58.12	254.96 ± 61.18	0.007
<b>Hospital stay (day)</b>	16.02 ± 14.65	8.15 ± 1.95	< 0.0001
<b>Death, No. (%)</b>	6 (3.9)	0 (0)	0.01

Abbreviations: AVR, Aortic valve repair/reconstruction; BMI, body mass index; Cr, creatinine; DM, diabetes mellitus; FBS, fasting blood sugar; HTN, hypertension; MVR, mitral valve repair/reconstruction; POPC, postoperative pulmonary complication; PVR, Pulmonary valve repair/reconstruction; TVR, Tricuspid valve repair/reconstruction; SPAP, systolic pulmonary artery pressure.

in coordination with several articles (7, 8). It seems that abnormal preoperative spirometry values lead to better management of these patients with bronchodilator and their treatment with acute respiratory symptoms. We had a few patients with COPD and cannot make conclusions in this regard.

The risk of postoperative pulmonary complications in-

creases significantly only between 70 and 80 years, in patients who have no other pulmonary risk factors (9). In the current study, age had a significant association with POPC. Mortasawi et al. reported that age could be a 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

**Table 4.** The Use of Blood and Blood Products in Two Groups of Patients<sup>a</sup>

	With POPC	Without POPC	P-Value
<b>PC</b>			
Intraoperative	37 (42)	32 (35.6)	0.37
24 h postoperative	20 (22.2)	9 (10)	0.02
48 h postoperative	15 (16.7)	11 (12.2)	0.39
72 h postoperative	19 (27.1)	1 (4)	0.01
<b>FFP</b>			
Intraoperative	9 (10.2)	2 (2.2)	0.02
24 h postoperative	2 (2.2)	1 (1.1)	0.56
48 h postoperative	2 (2.2)	0 (0)	0.15
72 h postoperative	3 (4.3)	0 (0)	0.29
<b>PLT</b>			
Intraoperative	7 (8)	5 (5.6)	0.52
24 h postoperative	3 (2.2)	2 (2.2)	0.9

Abbreviations: FFP, Fresh frozen plasma; PC, packed cell; PLT, platelet; POPC, postoperative pulmonary complication.  
<sup>a</sup>Values are expressed as No. (%).

**Table 5.** Multivariate Analysis (Logistic Regression)

Variables	Regression Coefficient	SE	P Value	Odds Ratio	95% CI
Age	0.05	0.02	0.02	1.05	1.00 - 1.10
AVR	0.12	0.43	0.76	1.13	0.48 - 2.64
PVR	-0.37	0.66	0.56	0.68	0.18 - 2.49
HTN	0.77	0.39	0.04	2.17	1.01 - 4.70
Smoke	0.72	0.42	0.08	2.06	0.89 - 4.74
Surgery time, h	0.004	0.003	0.25	1.004	0.99 - 1.01
Pump time, min	0.01	0.10	0.06	1.01	0.99 - 1.03
Cross clamp time, min	0.02	0.01	0.13	0.97	0.94 - 1.007
ABG (AIR), PO <sub>2</sub>	0.01	0.01	0.42	1.01	0.98 - 1.03
ABG (FIO <sub>2</sub> -100), PO <sub>2</sub>	-0.004	0.004	0.25	0.99	0.98 - 1.003
COPD	1.01	0.86	0.24	2.76	0.50 - 15.12
BMI	1.28	0.70	0.01	3.60	1.25 - 10.42

Abbreviations: AVR, Aortic valve repair/ reconstruction; BMI, body mass index; COPD, chronic obstructive pulmonary disease; HTN, hypertension; PVR, Pulmonary valve repair/ reconstruction.

patients older than 50 years old were most prone to major pulmonary complications, especially infectious complications (11).

In our study, patients with Hypertension had more POPC. Although increased number of POPC among patients with diabetes mellitus was clinically important, this increase was not statistically significant. Silva DR et al., reported the same findings in patients with diabetes (7).

We found a significant relationship between BMI and POPC, as the patients with higher BMI were more prone to post-op pulmonary complications. Obese patients are susceptible to ineffective coughing, basal atelectasis and progressive hypoxia, facilitating infection (7).

Systolic PAP estimated by ECHO, present before any cardiac procedure, is an important factor in cardiac surgery associated with increased morbidity and mortality. Prevalence of pulmonary hypertension in cardiac surgery pa-

tients will increase parallel with severity of illness (12). In our findings, SPAP was associated with complications after surgery.

As it shown in Table 4, the use of packed cell (PC) 24 and 72 hours after surgery was significantly higher in patients with POPC in comparison with patients without POPC ( $P < 0.05$ ). However, the use of fresh frozen plasma (FFP) during surgery was significantly higher in patients with POPC ( $P = 0.02$ ), but there were no significant differences between groups regarding use of FFP postoperatively ( $P > 0.05$ ); we may conclude that infusion of FFP during the operation may increase post op complication and perhaps there might be a correlation with extracorporeal oxygenation and FFP transfusion.

This study was done as part of a larger study, which covered all kinds of heart surgeries including coronary artery bypass graft and congenital heart disease, the data

of which will be discussed in the future separately and in combination. We also had a special focus on respiratory aspects of these patients that will later be discussed separately. We think that precise definition of POPC needs a larger scale study to define all complications on a larger population.

### 5.1. Conclusion

The cumulative incidence of postoperative pulmonary complications was 50% at our center with a mortality rate of 6.6% (6 of 90) and the overall mortality among all patients was 3.3% (6 of 180).

The most important risk factors associated with POPC in our study were age, type of valvular surgery, BMI, HTN, history of smoking, surgery time, pump time, cross clamp time, and PO<sub>2</sub> and O<sub>2</sub> sat in ABG. According to the multivariate analysis, the variables that increased the chance of POPC were age, BMI and HTN.

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### Footnotes

**Authors' Contribution:** Hasan Allah Sadeghi, conception and design, conducting the project, and final approval of the article; Reza Alirezayeh Tabrizi, data collection; Behshid Ghadrdooost, analysis and preparation of the manuscript; Rasoul Azarfarin, clinical evaluation of patients.

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