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Research Article

Association of Restrictive and Obstructive Lung Pattern on Post-Operative Pulmonary Complications After Cardiac Surgery: A Prospective Cohort Study

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Abstract

Objective: To determine the frequency of post-operative pulmonary complications (PPCs) after cardiac surgery and association of pre-operative pulmonary factors with incidence of PPCs.

Methods: This cohort study included 623 patients who underwent cardiac surgery using coronary artery bypass grafting (CABG), congenital heart surgeries, or valvular heart surgery. Incidence of PPCs and risk factors of PPCs were noted. One-way ANOVA and chi-square test were applied to determine the association of pre-operative and intraoperative risk factors with incidence of PPCs.

Results: Post-operative pulmonary complications occurred in 362(58.1%) patients. Most common postoperative pulmonary complication was pleural effusion that occurred in 192(30.9%) patients, atelectasis in 151(24.2%) patients, diaphragm dysfunction in 77(12.4%) patients, pneumonia 47(7.5%), pneumothorax 79(2.7%), and acute respiratory distress syndrome (ARDS) and pulmonary edema (PE) in 46 (6.5%) patients. PE/ARDS was very less common in obstructive patients than in restrictive and normal subjects (p=0.010). The frequency of other post-operative complications was not statistically different among study groups (p>0.05). Operative mortality was 15 cases (2.4%) and there were no significant differences in outcomes across pulmonary and non-pulmonary patients (p>0.05). The mean length of stay in ICU was about 3.5 days, length of stay in hospital was around 16 days, and intubation time was just 740 minutes. Mean ventilation time(min) tended to be statistically different among groups (p=0.059). we found no important difference in them. Pulmonary edema or ARDS showed significant in these patients. Number of ARDS and Pulmonary edema was significantly higher in restrictive group in comparison with other groups.

Conclusion: Despite higher amount of PPC and LOS in ICU and hospital, in regard to PPCs and in hospital outcomes, we found no statistically significant difference between obstructive, restrictive and normal groups, but there was significant difference in some laboratory and demographic variables (ASA class, eGFR, diabetes, TSH and history of morning fatigue,) in between them.

Keywords: Coronary artery bypass grafting; pulmonary complications; valvular heart surgery; obstructive lung pattern; restrictive lung pattern

Background

Patients with pulmonary disease either obstructive or restrictive lung pattern, in comparison with normal patients may have more intraoperative or post-operative pulmonary complications (PPCs). There is a concern that these kinds of pulmonary disorders may lead to prolonged length of stay (LOS) in hospital and even increase in death rate. Regardless of the type of surgery, PPCs when happen, may prolong hospitalization time [1]. In another study, restrictive pattern on spirometry was associated with a statistically significant increase in mortality after coronary artery bypass grafting (CABG). In this study trend was towards increased incidence of postoperative MI and longer hospital LOS [2]. In another study risk of postoperative pulmonary complications in patients undergoing thoracic or non-thoracic surgery in patients with interstitial lung disease (ILD) population was elevated Lawrence et al. [3] suggested that the severity of airways obstruction as measured by spirometry may not be an independent predictor of pulmonary complications even in high-risk procedures [4] Our study in cardiac valve surgery patients and in another unpublished study in all cardiac surgery showed the same result [5]. In one study the higher postoperative mortality rate in patients with severe COPD, CABG was solely accounted for post operation complication [6]. Despite presence of several study in this field, the correlation between groups with obstructive, restrictive and normal pattern in spirometry before cardiac surgery with PPC are not clear. In this article we are going to evaluate these relationships.

Methods and Materials

Study Design

This cross-sectional prospective cohort study designed to determine the incidence of pulmonary complications after cardiac surgery in patients with pulmonary abnormality. During 6 months from September 2016 to Mach 2017 all consecutive adult patients more than 18 years of age, who were candidates for CABG, congenital heart surgeries, or valve surgery in Rajaei Cardiovascular Medical and Research Center were enrolled. All patients had lab evaluation and spirometry measurement before surgery and followed during admition time with no further intervention. Emergency surgeries were excluded. We followed Helsinki protocol and our local ethical committee approved the study. Also, Iran University of Medical Sciences covered all expenses.

Demographic Data

History of comorbid diseases such as pulmonary function tests, presence of diabetes mellitus, renal failure, respiratory disease, and laboratory tests of patients were obtained from their documents or were asked directly from patients. Complete history, vital signs and clinical examination, chest X-ray, pulse oximetry, electrocardiogram, echocardiography, and complete blood test were taken, as a routine practice, to detect patient's status. Arterial blood gas obtained through the arterial access line, on room air and then after 15 minutes giving 100% oxygenation while on ventilator, and recorded in a special sheet. All of patients received general anesthesia and put on pump oxygenator during surgery, as it is routinely done at our hospital. All surgeries were done via median sternotomy. Cold blood cardioplegin was used for cardiac arrest. At our intensive care unit (ICU), the patients are routinely extubated when they are hemodynamically stable and able to breathe adequately. After extubation, oxygen saturation (SPO2) is maintained above 90% by supplemental oxygen through the mask or nasal cannula, and patients could leave their bed as soon as general condition and patients tubing allowed. Further special evaluation was provided if the patient had complications requiring diagnostic tests or procedures based on specialist consult. To obtain the amount of total incidence of complications, the frequency of all morbidity in 24, 48, 72 hours after surgery, after leaving the ICU and finally before discharge from hospital were summed. All radiography and CT reviewed by our expert pulmonologists [7,8].

Patient Groups

Based on American Thoracic Society (ATS) statement, all patients with Forced Expiratory Volume to Forced Vital Capacity (FEV1/FVC) below 5th percentile of Lower Limit of Normal (LLN) considered as obstructive flow limitation (Obstructive Group). A restrictive lung defect is characterized by a reduction in FVC below the 5th percentile of the predicted value, and a normal or higher than normal FEV1/VC. Normal FEV1 and FVC and FEV1/FVC above 5th percentile characterized as Normal (normal group). We tried to match patients in "Normal Group" with "Restrictive and Obstructive Groups" based on age, gender and body mass index (BMI). Pattern and kinds of PPC compared across these groups and evaluated statistically.

Complication Definition

Pleural effusion (PE): PE was diagnosed based on Chest X-Ray (CXR) if blunting of costophrenic angle and loss of sharp silhouette of the ipsilateral hemidiaphragm in upright position, displacement of adjacent anatomical structures, or (in supine position) hazy opacity in one hemithorax with preserved vascular shadows [9-11] and also effusion need pleural catheter and evacuation. Effusion on CT, echocardiography and sonography also included as pleural effusion if this procedure was done for other reason and showed effusion in pleural space even if effusion not depicted in chest radiography.

Pneumonia: It was diagnosed by CXR with at least one of the following: infiltrate, consolidation, cavitation; plus at least one of the following: fever >38 °C with no other cause, white cell count <4 or >12×109, >70yr of age with altered mental status with no other cause; plus at least two of the following: new purulent/changed sputum, increased secretions/suctioning, new/worse cough/ dyspnoea/tachypnoea, rales/ bronchial breath sounds, worsening gas exchange. [9-11]

Hospital Acquired Pneumonia (HAP) or Ventilator Associated Pneumonia (VAP): Pneumonia either HAP or VAP diagnosis, were based on presence of new pulmonary infiltrates on chest X ray or CT scan, fever, cough or sputum after operation and if antibiotic started for pulmonary infiltrate based on diagnosis of pulmonologist or infectious specialist. Leukocytosis is common after these kinds of cardiac operations, and we considered HAP in our patients if they had at least two or more of the above findings plus leukocytosis. VAP was accepted if the patient remained intubated more than 48 hours and had other criteria of pneumonia.

Diaphragm Dysfunction or Paralysis: It was diagnosed if significant permanent diaphragm elevation was seen on 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 in ICU. All newfound, significant left diaphragm elevation, that persist in last radiography at discharge time considered as diaphragm paralysis even if no sonography or fluoroscopy is done for diagnosis.

Atelectasis: Lung opacification with mediastinal shift, hilum or hemidiaphragm shift towards the affected area, with compensatory hyperinflation in adjacent non-atelectatic lung19,20,21 Plate atelectasis, lobar, multi-lobar atelectasis and or whole lung collapse all categorized and considered as atelectasis.

Pneumothorax: Air in the pleural space with no vascular bed surrounding the visceral pleura.19,20,21

ARDS/Pulmonary Edema: Diagnosis of ARDS/Pulmonary Edema was based on radiographic findings and clinical condition of patient. It was impossible to follow Berlin definition of ARDS and therefore edema and ARDS considered as one entity.

Statistical Analysis: Results are presented as mean ± standard deviation (SD), or frequencies with percentages, as appropriate. Comparisons across groups were made with one-way analysis of variance (ANOVA), chi-square test, chi-square test for trend, or Fisher's exact test as appropriate. No statistically significant skewness was met in frequency distribution of numeric variables ($p>0.05$). All analyses were performed using SPSS version 19.0 software (SPSS, Inc., Chicago, IL). A 2-tailed p-value of ≤0.05 was considered statistically significant.

Results

In this study Groups of patients classified and homogenized to reduce influence of other confounding factors. As we can see in Table 1, all patients' groups are matched for age, gender and BMI. Demographic, historical and laboratory characteristics of the subjects in each of obstructive, restrictive, and normal pulmonary conditions according to the ATS statement are shown in Table 1.

a. As can be seen in Table 1, the mean of age and BMI and the frequency distribution of gender are not statistically different across the three groups ($p>0.05$), as we attempted to match groups according to age, BMI and gender. History of morning fatigue was more common in restrictive patients ($p=0.010$). Also, restrictive patients had higher eGFR and FBS than patients with other pulmonary conditions ($p=0.016$ and $p=0.011$, respectively). Obstructive patients had higher creatinine level and less likely to be ASA class 1 and 2 compared to restrictive and normal subjects ($p=0.002$ and $p<0.001$, respectively). However, hypertension was more prevalent in obstructive patients, but it did not reach statistically significant difference ($p=0.083$). The rest of demographic, historical and laboratory characteristics did not statistically differ across the three groups ($p>0.05$) Table 1. Spirometric values of the subjects are depicted in Table 1.

b. As can be seen, the level of both FEV1(mv) and FEV1(PP) are increased in normal subjects than in pulmonary patients ($p<0.001$). FVC (mv) and FVC(PP) levels showed reduction in restrictive patients compared to other groups ($p<0.001$). The level of FEV1/FVC(PP) and PEFR (PP) were statistically different across the three groups ($p<0.001$). The mean of MMEF was lowered in obstructive patients than in either group restrictive of normal ($p<0.001$) Table 2. Intraoperative characteristics of subjects are abstracted in Table 3. In obstructive patients, PO2_100 showed highly increase in normal patients compared to restrictive and normal subjects ($p<0.001$). Mechanical ventilation time tended to be statistically different among groups ($p=0.059$). The mean of PO2_air was lowered in obstructive patients than in either groups restrictive or normal ($p<0.021$), while none of the other intraoperative characteristics was statistically different across the three groups ($p>0.05$) Table 3. Table 4 demonstrates post-operative complications among the three groups. PE and ARDS was very less common in obstructive patients than in restrictive and normal subjects ($p=0.010$). The frequency of other post-operative complications was not statistically different among study groups ($p>0.05$). Table 5 suggests that there were no significant differences in outcomes across the three groups ($p>0.05$). In 623 subjects participated in this cross-sectional prospective cohort study, mortality was observed in just 15 cases (2.4%). The mean length of stay in ICU was about 3.5 days, length of stay in hospital was around 16 days, and intubation time was just 740 minutes Table 5.

Table 1: Demographic, historical, and laboratory characteristics of patients with obstructive, restrictive, and normal spirometry before cardiac surgery.

Variables	Total (n=623)	Obstructive (n=128)	Restrictive (n=222)	Normal (n=273)	P-value
Demographic characteristics					
Age (year)	55.80±13.95	56.13±13.86	54.27±15.15	56.88±12.88	0.112
BMI (kg/m2)	25.81±3.93	26.32±5.04	25.81±4.55	25.57±2.54	0.204
Gender Male Female	386(62.0) 237(38.0)	83(64.8) 45(35.2)	128(57.7) 94(42.3)	175(64.1) 98(35.9)	0.256
Historical and clinical characteristics					
Tobacco smoke	193(31.0)	48(37.5)	58(26.1)	87(31.9)	0.078
Opium usage	114(18.3)	28(21.9)	33(14.9)	53(19.4)	0.215
Home Bakery	86(13.8)	20(15.6)	33(14.9)	33(12.1)	0.537
Snoring	292(46.9)	56(43.8)	104(46.8)	132(48.4)	0.69
Morning fatigue	254(40.8)	44(34.4)	108(48.6)	102(37.4)	0.01

Somnolence	185(29.7)	29(22.7)	66(29.7)	90(33.0)	0.109
Morning headache	112(18.0)	19(14.8)	45(20.3)	48(17.6)	0.433
suffocation	66(10.6)	11(8.6)	27(12.2)	28(10.3)	0.563
ESS	2.92±4.39	2.40±4.17	3.14±4.84	3.00±4.09	0.297
Neck circumference (cm)	36.74±3.32	36.92±3.13	36.66±3.62	36.71±3.16	0.769
Diabetes	174(27.9)	32(25.0)	66(29.7)	76(27.8)	0.636
Hypertension	211(33.9)	54(42.2)	70(31.5)	87(31.9)	0.083
Laboratory characteristics					
Hb(mg/dlit)	13.15±1.58	13.29±1.44	12.95±1.55	13.25±1.62	0.064
EGFR(mlit/min)	76.12±28.30	72.04±27.31	80.31±29.94	74.62±27.03	0.016
Cr(mg/dlit)	1.08±0.41	1.18±0.63	1.02±0.33	1.08±0.31	0.002
FBS(mg/dlit)	113.13±43.34	107.43±35.36	119.96±50.85	110.24±39.36	0.011
Uric acid(mg/dlit)	6.37±1.79	6.30±1.90	6.46±1.88	6.32±1.67	0.626
ASA class 1 2 3 4	118(18.9) 280(44.9) 161(25.8) 64(10.3)	11(8.6) 49(38.3) 52(40.6) 16(12.5)	39(17.6) 101(45.5) 60(27.0) 22(9.9)	68(24.9) 130(47.6) 49(17.9) 26(9.5)	<0.001
TSH(Iu/lit)	2.52±3.81(n=564)	1.94±1.07(n=116)	2.32±2.45(n=201)	2.95±5.24(n=247)	0.041
EF(%)	45.52±9.78	41.56±10.32	42.27±9.58	43.17±9.67	0.278
SPAP (cm H2) ≤25 26-35 36-45 >45	471(75.6) 107(17.2) 34(5.5) 11(1.8)	96(75.0) 20(15.6) 10(7.8) 2(1.6)	172(77.5) 39(17.6) 7(3.2) 4(1.8)	203(74.4) 48(17.6) 17(6.2) 5(1.8)	0.619

Data are presented as mean ± SD (standard deviation) or n(%). BMI; Body Mass Index, ESS; Epward Sleepiness Score, Hb; Hemoglobin, eGFR; estimated Glomerular Filtration Rate, Cr; Creatinine, FBS; Fasting Blood Sugar, SPAP; Systolic Pulmonary Arterial Pressure, TSH; Thyroid Stimulating Hormone, EF; Ejection Fraction, PO2 Air; Pressure of Oxygen in room air.

Table 2: Spirometric values of patients with obstructive, restrictive, and normal spirometry.

Variables	Total (n=623)	Obstructive (n=128)	Restrictive (n=222)	Normal (n=273)	P-value
FEV1 (MV)	2.45±0.80	2.21±0.61	2.20±0.69	2.77±0.86	<0.001
FVC (MV)	2.95±1.01	3.22±0.82	2.37±0.83	3.30±1.02	<0.001
FEV1 (PP)	93.10±16.55	87.36±16.40	89.77±10.58	98.50±18.86	<0.001
FVC (PP)	90.43±16.35	98.09±16.62	79.66±8.64	95.59±16.51	<0.001
FEV1/FVC (PP)	107.88±13.59	88.09±7.85	119.26±7.98	107.89±7.19	<0.001
MMEF (PP)	2.84±1.17	1.47±0.64	3.20±0.87	3.18±1.09	<0.001
PEFR (PP)	6.40±2.30	6.21±1.81	5.46±2.49	7.26±2.01	<0.001

Data are presented as mean ± SD (standard deviation). MV; Measured Values, PP; Percent Predicted, FEV1; Forced Expiratory Volume at first second, FVC; Forced Vital Capacity, MMEF; Maximum Mid Expiratory Flow rate, PEFR; Peak Expiratory Flow

Table 3: Some intraoperative characteristics of patients with obstructive, restrictive, and normal spirometry at the time of cardiac surgery.

Variables	Total (n=623)	Obstructive (n=128)	Restrictive (n=222)	Normal (n=273)	P-value
PO2_100	274.72±74.62	257.63±66.73	273.95±78.68	312.52±69.94	<0.001
PO2_air	76.03±12.47 (n=439)	74.26±12.49 (n=83)	77.80±10.79 (n=155)	77.01±14.71 (n=201)	0.021
Clamp time (min)	54.97±27.17	56.77±26.27	56.11±27.32	53.21±27.46	0.351
Pump time (min)	92.61±39.84	95.14±40.89	93.65±40.48	90.58±38.86	0.502

Skin to skin time (min)	245.75±73.23	246.75±68.16	248.95±71.04	242.68±77.31	0.63
MV time (min)	585.66±348.96	629.86±341.02	543.80±314.03	598.99±376.17	0.059
Blood transfusion	415(66.6)	82(64.1)	159(71.6)	174(63.7)	0.143

Data are presented as mean ± SD (standard deviation) or n(%). PO2_100; Arterial Pressure of Oxygen after taking 100 percent Oxygen, PO2_Air; Arterial Pressure of Oxygen on Room Air, MV time = Mechanical Ventilation

Table 4: Comparison of Post-operative complications in patients with obstructive, restrictive, and normal spirometry.

Variables	Total (n=623)	Obstructive (n=128)	Restrictive (n=222)	Normal (n=273)	P-value
Total	362(58.1)	81(63.3)	130(58.6)	151(55.3)	0.316
Pneumonia	47(7.5)	10(7.8)	22(9.9)	15(5.5)	0.179
Pleural Effusion	192(30.9)	44(34.4)	67(30.2)	81(29.8)	0.626
Diaphragm dysfunction	77(12.4)	11(8.6)	28(12.6)	38(13.9)	0.316
Atelectasis	151(24.2)	29(22.7)	54(24.3)	68(24.9)	0.886
Pneumothorax	17/621(2.7)	4/127(3.1)	9(4.1)	4/272(1.5)	0.205
PE and ARDS	40/620 (6.5)	1/127 (0.8)	20 (9.0)	19/271 (7.0)	0.01

Data are presented as n(%). PE; Pulmonary Edema, ARDS; Adult Respiratory Distress Syndrome.

Table 5: Comparison of outcome of cardiac surgery in patients with obstructive, restrictive, and normal spirometry.

Variables	Total (n=623)	Obstructive (n=128)	Restrictive (n=222)	Normal (n=273)	P-value
Death	15(2.4)	4(3.1)	7(3.2)	4(1.5)	0.399
LOS in ICU (day)	3.48±1.13	3.55±1.36	3.55±1.25	3.38±0.88	0.164
LOS in hospital (day)	16.28±7.68	16.17±6.77	16.31±7.33	16.30±8.37	0.984
Intubation Time (min)	739.91±701.25 (n=598)	709.01±559.82 (n=123)	767.58±808.59 (n=211)	732.20±669.10 (n=264)	0.742

Data are presented as mean ± SD (standard deviation) or n(%). LOS; Length of Stay, ICU; Intensive Care Unit.

Discussion

By evaluation of PubMed and Google we found no study that compare patients with restrictive and obstructive lung disease regard to PPCs with normal patients. Cardiac surgery with pump perfusion is a high-risk surgery with significant PPCs and we are routinely encounter these complications in our center. In this study we are going to define prevalence of POPCs in all kinds of cardiac surgery and compare those patients with restrictive or obstructive airflow limitation with those with no known pulmonary disease and normal spirometry values. As it is obvious in Table 2, in regard to spirometry values we can show that because of categorization, all three groups of patients are significantly different, and we are comparing these groups from PPCs point of view. There are some pulmonary complications after non-emergency cardiac surgery but can be life threatening in rare cases. The documented incidence of PPCs ranges from 3% to 16% after CABG and 5%-7% after valvular heart surgery [9-12]. The reported frequency of pulmonary complications after cardiac surgery varies from 6% to 70% depending upon the criteria used to define pulmonary complications [13]. Furthermore, patients undergoing cardiac surgery often have underlying pulmonary illnesses such as obstructive lung disease (e.g., chronic obstructive pulmonary disease) and restrictive lung disease (e.g., congestive heart failure, and interstitial lung disease,) which may increase their susceptibility to postoperative respiratory problems. In our study, PPCs occurred in 362 (58.1%) patients after surgery, with 81 (63.3%) incidence in patients with obstructive lung pattern ,130 (58.6%) in patients with restrictive lung pattern and 151 (55.3%) in patient with normal lung pattern. The incidence of PPCs in our study was comparable to the results of other international studies. Otherwise, incidence of pulmonary complications after cardiac surgery were not significantly different in patients with normal and abnormal pulmonary pattern.

Main objective of this study was to compare patient with obstructive and restrictive pattern of flow limitation in spirometry with those with normal spirometry about PPC after all types of cardiac surgery, Length of stay in ICU and hospital (cost of operation), intubation time, and death of patient candidate for cardiac surgery. There were not any significant differences between those patients with normal and abnormal pulmonary function. Although the impact of severe lung disease such as COPD on patients undergoing cardiac surgery was traditionally considered potentially dangerous for cardiac surgery, we did not find any. About patients undergoing CABG, COPD was reported to be an independent risk factor for postoperative morbidity and/or mortality [14,15] However, because of the recent improvements in anesthesia, cardiac protection, and surgical techniques, as well as the advances in preoperative pulmonary evaluation and medical optimization, it becomes possible to perform CABG with acceptable morbidity and mortality rates in patients with high-risk. There are many studies have reported that patients with mild to moderate COPD or even severe COPD did not have a higher risk of postoperative mortality and morbidity rates than those without COPD [16-18] There were only two complications which was significantly different in these tree groups. We found pleural effusion and ARDS were very less common in obstructive patients than restrictive and normal subjects. This finding could be explained by the fact that more patient with heart failure and cardiomegaly might have been included in our restrictive group.

To compare pulmonary complication and in hospital outcomes of our patient in these three groups, we found no important difference among them. Pulmonary edema or ARDS showed statistically significant in these patients. Number of ARDS and Pulmonary edema was significantly higher in restrictive group in comparison with obstructive and normal groups. This finding could be explained by the fact that more patient with heart failure and cardiomegaly might have been included in this group. Evaluation of ejection fraction of this patient showed more patient with heart failure categorized in restrictive group. Some limitations should be considered when interpreting the results in the present study. First, this study was cohort, and publication bias cannot be avoided because of its nature. Second, because of no internationally unified criteria have existed until recently, the definition of obstructive and restrictive lung pattern in published studies was various. In the present study, only spirometric pattern confirmed by a FEV1/FVC, FEV1, FVC, or by the diagnosis and/or treatment record were included. Although these inclusion criteria were aimed to diminish the potential bias in the lung disease definition, it might also induce bias in the results to some extent. Third, the included studies cover variety cardiac surgery (such as valvular, vascular cardiac surgery) and surgeon, during which variable surgery may occur in the operative and postoperative complications. These changes might affect the outcomes of interest [19,20].

Conclusion

Despite statistically significant correlation between high blood sugar, lower GFR, anemia and history of fatigue with PPCs, we found no statistically significant difference between obstructive, restrictive and normal groups, in regard to LOS in hospital and ICU and death.

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