## Original Article

# The Obstructive and Restrictive Spirometry Pattern and Post-Cardiac Surgery Pulmonary Complications

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## ABSTRACT

***Objectives:*** We sought to determine the frequency of postoperative pulmonary complications (PPCs) after cardiac surgeries in patients with obstructive, restrictive, and normal spirometry tests.

***Methods:*** This cohort study enrolled 623 patients who underwent cardiac surgeries at Rajaie Cardiovascular Medical and Research Center between 2017 and 2018 in 3 groups: obstructive, restrictive, and normal. The incidence of PPCs and their risk factors were noted. Associations between the incidence of PPCs and spirometry patterns and preoperative and intraoperative risk factors were evaluated statistically.

***Results:*** Among all the PPCs evaluated in the patients, pulmonary edema/acute respiratory distress syndrome was much less common in the group with obstructive airflow limitations than in the groups with restrictive or normal lung patterns ($P$=0.010). The frequencies of other PPCs were not statistically significantly different between the 3 study groups ($P$>0.05). Among all the evaluated outcomes, the mean ventilation time was statistically different between the groups ($P$=0.059). Additionally, the incidence rate of pulmonary edema/acute respiratory distress was statistically significantly higher in the group with restrictive airflow limitations than in the other 2 groups. Operative mortality occurred in 15 cases (2.4%), and there were no significant differences in outcomes between the group with PPCs and those without them ($P$>0.05).

***Conclusions:*** Whereas there were no statistically significant differences concerning PPCs and in-hospital outcomes between the groups with obstructive, restrictive, and normal lung patterns, the 3 groups were meaningfully different regarding the estimated glomerular filtration rate, diabetes, thyroid-stimulating hormone, and history of morning fatigue. ***(Iranian Heart Journal 2024; 25(2): 65-74)***

**KEYWORDS:** Coronary artery bypass grafting, Pulmonary complications, Valvular heart surgery, Obstructive lung pattern, Restrictive lung pattern

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Patients with pulmonary diseases, either with obstructive or restrictive lung patterns, may develop more intraoperative or postoperative pulmonary complications (PPCs) than patients with normal lung patterns. Obstructive and restrictive airflow limitations could lead to prolonged lengths of stay in the hospital, regardless of the type of surgery, and even increased death rates. [1] In a previous study, the restrictive pattern in spirometry was associated with a statistically significant rise in mortality after coronary artery bypass grafting (CABG); further, a trend existed toward increased incidence rates of postoperative myocardial infarction and prolonged lengths of hospital stay. [2] Another investigation reported an elevated risk of PPCs in patients with interstitial lung disease undergoing thoracic or non-thoracic surgery. [3] The results of another study suggested that the severity of airway obstruction as measured by spirometry might not be an independent predictor of PPCs, even in high-risk procedures. [4] Our previous study on patients undergoing cardiac valve surgery and our findings in another unpublished investigation on patients undergoing all kinds of cardiac surgeries showed similar results. [5] According to another study on patients with severe chronic obstructive pulmonary disease (COPD), CABG was solely responsible for all PPCs. [6]

Despite the sizable research into pulmonary diseases, the correlations between PPCs and pre-cardiac surgery obstructive, restrictive, and normal lung patterns in spirometry have yet to be elucidated. Accordingly, we conducted the present study to determine the frequency of pulmonary complications after cardiac surgeries and the associations between the incidence of such complications and perioperative pulmonary factors.

## METHODS

***Study Design:*** This prospective cohort study was designed to determine the incidence of PPCs after cardiac surgeries in patients with pulmonary abnormalities. During a 6-month period, from September 2016 through March 2017, all consecutive adult patients aged above 18 years who were candidates for CABG, congenital heart defects surgery, or valvular heart surgery at Rajaie Cardiovascular Medical and Research Center were enrolled. All the patients had laboratory evaluations and spirometry results before surgery and underwent follow-ups during their hospitalization with no further interventions. Patients undergoing emergency surgeries were excluded. The study protocol was approved by the institutional ethics committee and adhered to the Declaration of Helsinki. The entire cost for the conduct of this study was covered by Iran University of Medical Sciences.

***Demographic Data*:** The results of pulmonary function and laboratory tests, as well as a history of comorbid diseases such as diabetes mellitus and renal failure, were obtained either directly from the patients or indirectly from their hospital records. As a matter of routine, complete history taking, clinical examinations, chest X-rays, pulse oximetry, electrocardiography, echocardiography, and complete blood tests were performed for all the patients to determine their status. Additionally, arterial blood gas was measured through the arterial access line while the patient was breathing room air and then again after 15 minutes of administering 100% oxygenation while the patient was on the ventilator. The results were recorded in a special sheet. Moreover, the entire study population received general anesthesia and was placed on pump oxygenators during surgery, as it is done in our hospital routinely. All the surgeries were performed via a median sternotomy. Cold blood cardioplegia was used for cardiac arrest. At our ICU, the patients were extubated routinely when they were hemodynamically stable and able to breathe adequately. After extubation, oxygen saturation ($SPO_2$) was maintained above 90% by administering supplemental oxygen with masks or nasal cannula, and the patients could leave their beds as soon as their general conditions allowed it. Further special evaluations were provided if the patients had complications requiring diagnostic tests or procedures at the discretion of our specialists. The total incidence rate of complications was calculated by summing all morbidities at 24, 48, and 72 hours after surgery, after ICU discharge, and before hospital discharge. All the radiographic and computed tomography (CT) images were reviewed by our expert pulmonologists.

***Patient Groups:*** Based on the statement of the American Thoracic Society (ATS), all patients with a forced expiratory volume-to-forced vital capacity (FEV1/FVC) ratio below the fifth percentile of the lower limit of normal were considered to have obstructive flow limitations (the obstructive group). A restrictive lung defect was characterized by a reduction in FVC below the fifth percentile of the predicted value and a normal or higher-than-normal FEV1/VC. Normal FEV1/FVC and FEV1/FVC above the fifth percentile were defined as normal (the normal group). We tried to match the patients in the normal group with those in the restrictive and obstructive groups based on age, sex, and body mass index (BMI). The patterns and types of PPCs were compared between the 3 groups and evaluated statistically.

**Definitions of Complications**

***Pleural effusion:*** Pleural effusion was diagnosed based on chest X-rays if they illustrated the blunting of the costophrenic angle and the loss of the sharp silhouette of the ipsilateral hemidiaphragm in the upright position, the displacement of the adjacent anatomical structures, hazy opacity in 1 hemithorax with preserved vascular shadows (in supine position), [7-9] or the requirement for pleural catheters and evacuation. Effusion on computed tomography (CT), echocardiography, and sonography was also interpreted as pleural effusion if these procedures were done for other reasons and showed effusion in the pleural space even if the effusion was not depicted in the chest X-ray.

***Pneumonia:*** Pneumonia was diagnosed via chest X-rays with at least 1 of the following: infiltration, consolidation, and cavitation in addition to at least 1 of the following: fever (>38 °C) with no other causes, a white blood cell count <4 or >12×10, [9] age >70 years, altered mental status with no other causes, and at least 2 of the following: new purulent/changed sputum, increased secretions/suctioning, new/worse cough/dyspnea/tachypnea, rales/ bronchial breath sounds, and worsening gas exchange. [7-9]

***Hospital-acquired pneumonia or ventilator-associated pneumonia*:** The diagnosis of pneumonia, either hospital-acquired or ventilator-associated, was based on the presence of new pulmonary infiltrates on chest X-rays or CT scans, fever, and cough or sputum after surgery, and if antibiotics were started for pulmonary infiltrates based on the diagnosis of the pulmonologist or the infectious disease specialist. Leukocytosis is common after these types of cardiac surgeries, and we considered hospital-acquired pneumonia in our patients if they had at least 2 of the above findings plus leukocytosis. Ventilator-associated pneumonia was diagnosed if the patient remained intubated for more than 48 hours and had other criteria of pneumonia.

***Diaphragm dysfunction or paralysis**:* This complication was diagnosed if significant permanent diaphragm elevation was seen in the chest X-ray, and/or if ultrasonography confirmed decreased or absent contractions of the diaphragm muscles. Phrenic nerve conduction velocity and diaphragm electromyography were not available at our ICU. All new-found significant left diaphragm elevations that persisted in the last radiography at discharge were considered to be diaphragm paralysis, even if no sonography or fluoroscopy was done for diagnosis.

***Atelectasis:*** Atelectasis was defined as lung opacification with a shift in the mediastinum, hilum, or hemidiaphragm toward the affected area, with compensatory hyperinflation in the adjacent non-atelectatic lung. [7-9] Plate, lobar, and multilobar atelectasis and/or whole-lung collapse were all categorized as atelectasis.

***Pneumothorax****:* Pneumothorax was defined as the presence of air in the pleural space with no vascular bed surrounding the visceral pleura. [7-9]

***Acute respiratory distress syndrome (ARDS)/pulmonary edema (PE):*** The diagnosis of ARDS/PE was based on the radiographic findings and clinical conditions of the patients. It was impossible to follow the Berlin definition of ARDS; we, therefore, considered ARDS and PE to be a single entity.

### Statistical Analysis

The results were presented as mean ± standard deviation (SD) or frequencies with percentages, as appropriate. Comparisons between the groups were made using the one-way analysis of variance (ANOVA), the $\chi^2$ test, the $\chi^2$ test for trend, or the Fisher exact test, as appropriate. No statistically significant skewness was observed in the frequency distribution of the numerical variables ($P$>0.05). All the analyses were performed using SPSS, version 19.0 (SPSS, Inc, Chicago, IL). A 2-tailed $P$ value ≤0.05 was considered statistically significant.

## RESULTS

In this study, groups of patients were classified and homogenized to reduce the influence of confounding factors. Table 1 shows that all 3 groups were matched in terms of age, sex, and BMI.

The demographic, historical, and laboratory characteristics of the subjects in each of the obstructive, restrictive, and normal groups according to the ATS statement are presented in Table 1. As can be seen in Table 1, the mean age, the mean BMI, and the frequency distribution of sex were not statistically significantly different between the 3 groups ($P$>0.05). A history of morning fatigue was more common in the restrictive group ($P$>0.010). Thyroid-stimulating hormone was significantly lower in the obstructive and restrictive groups than in the normal group ($P$>0.041). Additionally, the restrictive group had higher estimated glomerular filtration rates and fasting blood sugar levels than did the other 2 groups ($P$=0.016 and $P$=0.011, respectively). Hypertension was more prevalent in the obstructive group, but the difference failed to constitute statistical significance ($P$=0.083). The rest of the demographic, historical, and laboratory characteristics did not statistically differ between the 3 groups ($P$>0.05) (Table 1).

The spirometric values of the subjects are depicted in Table 2, which shows that the levels of both FEV1 (mv) and FEV1 (percent predicted [PP]) were increased in the normal group by comparison with the obstructive and restrictive groups ($P$<0.001). The levels of FVC (mv) and FVC (PP) exhibited a drop in the group with restrictive lung patterns in comparison with the other 2 groups ($P$<0.001). The levels of FEV1/FVC (PP) and the peak expiratory flow rate (PP) were statistically significantly different between the 3 groups ($P$<0.001). The mean maximum mid-expiratory flow rate was decreased in the obstructive group compared with the restrictive and normal groups ($P$<0.001) (Table 2).

The intraoperative characteristics of the subjects are abstracted in Table 3. In the obstructive group, $PO_2$_100 showed a remarkable rise in the normal group compared with the restrictive and normal groups ($P$<0.001). The mechanical ventilation time tended to be statistically different between the 3 groups ($P$=0.059). The mean $PO_2$_air was reduced in the patients with obstructive airflow limitations by comparison with the other 2 groups of restrictive and normal lung patterns ($P$<0.021). None of the other intraoperative characteristics was statistically significantly different between the 3 groups ($P$>0.05) (Table 3).

**Table 1:** Demographic, Historical, and Laboratory Characteristics of the Groups With Obstructive, Restrictive, and Normal Spirometry Before Cardiac Surgery

| Variable | Obstructive (n=128) | Restrictive (n=222) | Normal (n=273) | *P* value | Total |
|---|---|---|---|---|---|
| Demographic Characteristics | | | | | |
| Age, y | 56.13±13.86 | 54.27±15.15 | 56.88±12.88 | 0.112 | 55.80±13.95 |
| BMI, kg/m$^2$ | 26.32±5.04 | 25.81±4.55 | 25.57±2.54 | 0.204 | 25.81±3.93 |
| Sex | | | | 0.256 | |
| male | 83(64.8) | 128(57.7) | 175(64.1) | | 386(62.0) |
| female | 45(35.2) | 94(42.3) | 98(35.9) | | 237(38.0) |
| Historical and Clinical Characteristics | | | | | |
| Tobacco smoking | 48(37.5) | 58(26.1) | 87(31.9) | 0.078 | 193(31.0) |
| Opium consumption | 28(21.9) | 33(14.9) | 53(19.4) | 0.215 | 114(18.3) |
| Home bakery | 20(15.6) | 33(14.9) | 33(12.1) | 0.537 | 86(13.8) |
| Snoring | 56(43.8) | 104(46.8) | 132(48.4) | 0.690 | 292(46.9) |
| Morning fatigue | 44(34.4) | 108(48.6) | 102(37.4) | 0.010 | 254(40.8) |
| Somnolence | 29(22.7) | 66(29.7) | 90(33.0) | 0.109 | 185(29.7) |
| Morning headache | 19(14.8) | 45(20.3) | 48(17.6) | 0.433 | 112(18.0) |
| Suffocation | 11(8.6) | 27(12.2) | 28(10.3) | 0.563 | 66(10.6) |
| ESS | 2.40±4.17 | 3.14±4.84 | 3.00±4.09 | 0.297 | 2.92±4.39 |
| Neck circumference, cm | 36.92±3.13 | 36.66±3.62 | 36.71±3.16 | 0.769 | 36.74±3.32 |
| Diabetes | 32(25.0) | 66(29.7) | 76(27.8) | 0.636 | 174(27.9) |
| Hypertension | 54(42.2) | 70(31.5) | 87(31.9) | 0.083 | 211(33.9) |
| Laboratory Characteristics | | | | | |
| Hb, mg/dL | 13.29±1.44 | 12.95±1.55 | 13.25±1.62 | 0.064 | 13.15±1.58 |
| eGFR, mL/min | 72.04±27.31 | 80.31±29.94 | 74.62±27.03 | 0.016 | 76.12±28.30 |
| Cr, mg/dL | 1.18±0.63 | 1.02±0.33 | 1.08±0.31 | 0.002 | 1.08±0.41 |
| FBS, mg/dl | 107.43±35.36 | 119.96±50.85 | 110.24±39.36 | 0.011 | 113.13±43.34 |
| Uric acid, mg/dL | 6.30±1.90 | 6.46±1.88 | 6.32±1.67 | 0.626 | 6.37±1.79 |
| TSH, IU/L | 1.94±1.07(n=116) | 2.32±2.45(n=201) | 2.95±5.24(n=247) | 0.041 | 2.52±3.81(n=564) |
| EF, % | 41.56±10.32 | 42.27±9.58 | 43.17±9.67 | 0.278 | 45.52±9.78 |
| SPAP, cm $H_2O$ | | | | 0.619 | |
| ≤25 | 96(75.0) | 172(77.5) | 203(74.4) | | 471(75.6) |
| 26-35 | 20(15.6) | 39(17.6) | 48(17.6) | | 107(17.2) |
| 36-45 | 10(7.8) | 7(3.2) | 17(6.2) | | 34(5.5) |
| >45 | 2(1.6) | 4(1.8) | 5(1.8) | | 11(1.8) |

Data are presented as mean ± SD or n (%).
BMI: body mass index; ESS: Epworth 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; ASA: American Society of Anesthesiologists

**Table 2:** Spirometric Values of the Groups With Obstructive, Restrictive, and Normal Spirometry

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

Data are presented as mean ± SD.
MV: measured values; PP: percent predicted; FEV1: forced expiratory volume in the first second; FVC: forced vital capacity; MMEF: maximum mid-expiratory flow rate; PEFR: peak expiratory flow rate

**Table 3:** Measured Intraoperative Characteristics of the Groups With Obstructive, Restrictive, and Normal Spirometry at the Time of Cardiac Surgery

| Intraoperative | | | | | |
|---|---|---|---|---|---|
| Variable | Obstructive (n=128) | Restrictive (n=222) | Normal (n=273) | *P* value | Total (N=623) |
| $PO_2$_100 | 257.63±66.73 | 273.95±78.68 | 312.52±69.94 | <0.001 | 274.72±74.62 |
| $PO_2$_air | 74.26±12.49 (n=83) | 77.80±10.79 (n=155) | 77.01±14.71 (n=201) | 0.021 | 76.03±12.47 (n=439) |
| Clamp time, min | 56.77±26.27 | 56.11±27.32 | 53.21±27.46 | 0.351 | 54.97±27.17 |
| Pump time, min | 95.14±40.89 | 93.65±40.48 | 90.58±38.86 | 0.502 | 92.61±39.84 |
| Skin-to-skin time, min | 246.75±68.16 | 248.95±71.04 | 242.68±77.31 | 0.630 | 245.75±73.23 |
| MV time, min | 629.86±341.02 | 543.80±314.03 | 598.99±376.17 | 0.059 | 585.66±348.96 |
| Blood transfusion | 82(64.1) | 159(71.6) | 174(63.7) | 0.143 | 415(66.6) |

Data are presented as mean ± SD or n (%).
$PO_2$_100: arterial pressure of oxygen on FIO2=100; $PO_2$_air: arterial pressure of oxygen on room air; MV time: mechanical ventilation time

**Table 4:** Comparisons of the Postoperative Pulmonary Complications Between the Groups With Obstructive, Restrictive, and Normal Spirometry

| Variable | Obstructive (n=128) | Restrictive (n=222) | Normal (n=273) | *P* value | Total (N=623) |
|---|---|---|---|---|---|
| Total | 81/128(63.3) | 130/222(58.6) | 151/273(55.3) | 0.316 | 362/623(58.1) |
| Pneumonia | 10/128(7.8) | 22/222(9.9) | 15/273(5.5) | 0.179 | 47/623(7.5) |
| Pleural effusion | 44/128(34.4) | 67/222(30.2) | 81/273(29.8) | 0.626 | 192/623(30.9) |
| Diaph. dysfunction | 11/128(8.6) | 28/222(12.6) | 38/273(13.9) | 0.316 | 77/623(12.4) |
| Atelectasis | 29/128(22.7) | 54/222(24.3) | 68/273(24.9) | 0.886 | 151/623(24.2) |
| Pneumothorax | 4/127(3.1) | 9/222(4.1) | 4/272(1.5) | 0.205 | 17/621(2.7) |
| ARDS/PE | 1/127 (0.8) | 20/222 (9.0) | 19/271 (7.0) | 0.010 | 40/620 (6.5) |

Data are presented as n (%), and the number of each variable is reported over the total number of each group.
ARDS: acute respiratory distress syndrome; PE: pulmonary edema; Diaph.: diaphragm

**Table 5:** Comparisons of the Outcomes of Cardiac Surgeries Between the Groups With Obstructive, Restrictive, and Normal Spirometry

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

Data are presented as mean ± SD or n (%).
LOS: length of stay

Table 4 demonstrates PPCs among the 3 groups. ARDS/PE was much less common in the group with obstructive lung patterns in spirometry than in the restrictive and normal groups (*P*=0.010). The frequencies of the other PPCs were not statistically significantly different between the 3 study groups (*P*>0.05).

Table 5 indicates no significant differences in outcomes between the 3 groups of obstructive, restrictive, and normal lung patterns (*P*>0.05). In the 623 patients who participated in this cross-sectional prospective cohort study, mortality was observed in only 15 cases (2.4%). The mean length of stay in the ICU was about 3.5 days, the mean length of stay in the hospital was around 16 days, and the mean intubation time was just 740 minutes (Table 5).

## DISCUSSION

Our search in PubMed and Google yielded no study on the comparison between patients with obstructive, restrictive, and normal lung patterns in spirometry concerning PPCs following cardiac surgeries. Cardiac surgical operations with pump perfusion are deemed a high-risk procedure with significant PPCs, which we routinely encounter in our center. In the current study, we sought to determine the prevalence of PPCs in all types of cardiac surgeries and compare patients with restrictive or obstructive airflow limitations with those with no known pulmonary diseases and normal spirometry values.

As is clearly depicted in Table 2, our 3 study groups of obstructive, restrictive, and normal lung patterns in spirometry were significantly different as a consequence of our categorization; we compared these groups vis-à-vis PPCs.

There are some pulmonary complications after non-emergency cardiac surgeries. They are, however, life-threatening only on rare occasions. The documented incidence rate of PPCs ranges from 3% to 16% after CABG and from 5% to 7% after valvular heart surgery. [10-13] Chumillas et al [14] reported variations in the frequency of PPCs after cardiac surgeries, from 6% to 70%, depending upon the criteria applied to define such complications. Furthermore, patients undergoing cardiac surgeries often have underlying pulmonary illnesses, such as obstructive lung disease (eg, COPD) and restrictive lung disease (eg, congestive heart failure and interstitial lung disease), which may increase their susceptibility to postoperative respiratory problems. In our study, PPCs occurred in 362 patients (58.1%): 81 (63.3%) with obstructive lung patterns, 130 (58.6%) with restrictive lung patterns, and 151 (55.3%) with normal lung patterns. The incidence of PPCs in our study is comparable to the results of other international studies. Otherwise, the incidence of PPCs was not significantly and meaningfully different between our patients with normal and abnormal pulmonary function test patterns (neither in the restrictive group nor in the obstructive group).

Our main objective in the current investigation was to compare patients with obstructive and restrictive patterns of flow limitations in spirometry with those with normal spirometry with respect to PPCs after all types of cardiac surgeries. To that end, we compared our 3 study groups in terms of the length of stay in the ICU, the length of stay in the hospital (costs of surgery), the intubation time, and mortality after cardiac surgical operations. We found that these variables were not statistically significantly different between the groups with normal and abnormal pulmonary functions.

Although the impact of severe lung diseases, such as COPD, on patients undergoing

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cardiac surgeries was traditionally considered potentially dangerous, we encountered no such problem in our investigation. With regard to patients undergoing CABG, COPD was reported to be an independent risk factor for postoperative morbidity and/or mortality. [15, 16] Nonetheless, recent improvements in anesthesia, cardiac protection, and surgical techniques, as well as advances in preoperative pulmonary evaluations and medical optimization, have made it possible to perform CABG with acceptable morbidity and mortality rates in high-risk patients. Numerous studies have reported that patients with mild-to-moderate COPD or even severe COPD do not have a high risk of postoperative mortality and morbidity by comparison with those without COPD. [17-19]

We detected only 2 PPCs that were statistically significantly different between our 3 study groups. Our results revealed that ARDS/PE was much less common in the obstructive group than in the groups with restrictive and normal lung patterns. We likely recruited more patients with heart failure and cardiomegaly in our restrictive group. However, we supposed that if we divided COPD patients into subgroups based on the severity index, there might be some differences in PCPs and outcomes. More robust results need larger samples and perhaps different designs.

Our comparisons of PPCs and in-hospital outcomes between the groups with normal and abnormal pulmonary functions showed no statistically meaningful differences. Only ARDS/PE exhibited a statistically significant difference between the 3 groups: the incidence rate of PE/ARDS was statistically significantly higher in the restrictive group than in the obstructive and normal groups. Despite the fact that the restrictive pattern in spirometry may come from heart failure, this finding can be explained by the possible inclusion of more patients with heart failure and cardiomegaly in the restrictive group. Our evaluation of the patients in terms of the ejection fraction demonstrated that more cases of heart failure were categorized in the restrictive group.

Some limitations should be considered in the interpretation of the results in the present study. Firstly, this investigation was a cohort study, and publication bias could not be avoided because of its nature. Secondly, because no internationally unified criteria have existed until recently, the definitions of obstructive and restrictive lung patterns in published studies have varied. In the present study, we included only spirometric patterns confirmed by FEV1/FVC, FEV1, or FVC, or by the diagnosis and/or treatment records. Although we employed these inclusion criteria to diminish the potential bias in the definition of lung disease, our action might have also induced bias in the results to some extent. Thirdly, the studies cited herein cover various cardiac surgeries (eg, valvular and vascular) and surgeons, with several intra- and postoperative complications, which might have influenced the outcomes of interest.

## CONCLUSIONS

Despite a statistically significant correlation between PPCs and high blood sugar levels, low estimated glomerular filtration rates, anemia, and history of fatigue, we found no statistically meaningful differences between our obstructive, restrictive, and normal groups in regard to the length of stay in the hospital, the length of stay in the ICU, and in-hospital mortality. Evaluation of patients with more complex pulmonary function tests and using plethysmography, diffusing capacity of the lungs for carbon monoxide (DLCO), and impulse oscillometry (IOS) in larger-scale studies may help study the effects of restrictive and obstructive lung patterns on PPCs and surgical outcomes more comprehensively.

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## Financial Disclosure

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**Conflict of Interest:** Hereby, we disclose that there was no conflict 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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