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# Concordance between ARISCAT risk score and cardiopulmonary exercise test values in risk prediction of postoperative pulmonary complications of major abdominal surgeries in a tertiary cancer hospital: A cross-sectional study

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## Abstract

**Background and Aims:** Pulmonary complications are common after surgery. They include vascular thrombosis, pneumonia, respiratory failure (RF), and pain-related atelectasis. There are a number of models to predict the risk of postoperative respiratory events other than thrombosis. The aim of this study was to explore the correlation of assess respiratory risk in surgical patients in Catalonia (ARISCAT) scoring and cardiopulmonary exercise test (CPET) values in prediction of postoperative pulmonary complications (PPCs).

**Methods:** Cancer patients referred to a tertiary hospital for elective major abdominal surgeries were studied. Patients were evaluated by ARISCAT score and then CPET was performed to determine the risk of surgery based on maximal oxygen consumption ($VO_2$) value. Patients were followed for RF occurrence up to 72 h after surgery. Finally, the concordance of ARISCAT score and CPET values was evaluated in risk prediction of PPCs.

**Results:** The results showed that parameters $VO_2$, ARISCAT score, and anaerobic threshold could predict postoperative RF. Of these parameters, ARISCAT showed the highest sensitivity (100%) and the highest specificity (90.5%) compared with other parameters (Youden's *J* statistic = 0.905). However, $VO_2$ value showed the highest validity. The percentage of agreement between different subgroups (low, medium, and high) of both criteria ($VO_2$ and ARISCAT) was equal to 81.45% ($p < 0.001$) and the $\varkappa$ coefficient of the given weight was equal to 0.54 ($p < 0.001$), indicating a good agreement between these two criteria.

**Conclusion:** ARISCAT scoring showed high sensitivity and specificity to PPCs in cancer patients and good correlation with CPET value for prediction of PPCs. Therefore, it is a reliable and robust risk prediction tool in major abdominal surgeries on cancer patients.

KEYWORDS
abdominal surgery, ARISCAT, cancer, cardiopulmonary exercise test, postoperative pulmonary complications

## 1 | INTRODUCTION

Postoperative pulmonary complications (PPCs) commonly occur after intrathoracic and abdominal surgeries resulting in mortality and morbidity ranging from 0.3%–2% to 14%–30%. The prevalence of PPC is higher than postoperative cardiovascular events.[1] Following major surgeries, respiratory function returns to normal within 6 weeks.[2] There are measures to reduce PPC including smoking cessation, anemia correction, ventilation strategies during surgery, and management of neuromuscular blocking drugs.[3] More than 30 million major surgeries are performed annually in the United States, where the prevalence of PPC is between 1% and 23%. Currently, most of these complications include vascular thrombosis, pneumonia, respiratory failure (RF), and pain-induced atelectasis.[4,5] Numerous studies have shown that pulmonary complications are much more common than cardiac complications, the most common of which is RF after surgery.[6] This complication not only affects mortality but also has significant morbidity, which increases the length of hospital stay between 13 and 17 days.[7,8] On the other hand, it increases the rate of reintubation during the first 72 h after surgery. Furthermore, pneumonia or RF causes a 42%–47% increase in costs in tertiary care centers.[9]

Respiratory complications begin immediately after induction of general anesthesia. After a decrease in level of consciousness, apnea following sedation, and onset of controlled mechanical ventilation, the response of respiratory system to hypercapnia and hypoxia changes.[10] The function of the respiratory muscles also alters immediately after induction of anesthesia. The physical shape of the diaphragm arch changes, its position moves toward the dependent areas and contact areas with the chest wall are reduced. This condition causes a change in muscle tone at the end of the exhalation. Consequently, functional residual capacity (FRC) decreases by 15%–20% compared to the awake and standing status.[11] Reduction of FRC along with disproportionate distribution of regional ventilation following positive pressure ventilation and, reduction of cardiac output following mechanical ventilation with positive pressure cause a mismatch in ventilation to perfusion (V/Q) ratio, elevation of the alveolar dead space, and impairment in oxygen delivery and carbon dioxide excretion.[12]

In addition, atelectasis occurs in more than 75% of patients receiving general anesthesia with neuromuscular blockers and commonly seen in dependent areas of lungs on chest imaging. Postoperative pain, changes in the position of diaphragm, and decrease in FRC increase the risk of atelectasis. Prolonged atelectasis predisposes pneumonia. The strategies to decrease the risk of PPC such as smoking cessation, oral hygiene care, pain control, and treatment of underlying pulmonary disease are well known. There are several pulmonary risk stratification tools. The assess respiratory risk in surgical patients in Catalonia (ARISCAT) risk score is widely used.[13] The use of validated prediction risk models helps to recognize high risk patients and exert measures to reduce PPCs. For example, inspiratory muscle training before surgery reduces PPCs in high-risk patients.[14] The ARISCAT variables are age, preoperative oxygen saturation, history of pneumonia in last month, anemia, site of surgery, estimated duration, and urgency of procedure. In addition to its simplicity, the risk score is an externally validated model with sufficient prediction power among existing risk scores.[15] However, it seems that ARISCAT risk score has short comings and conflicting results in patients with certain types of cancer, comorbidities, and underlying lung disease.[16] Cardiopulmonary exercise test (CPET) is commonly used to predict risk in intrathoracic surgeries, especially lung cancer resections. However, its role is not well-defined in non-thoracic surgeries.[17]

In this study, it was aimed to assess the concordance of ARISCAT risk score and CPET in prediction of PPCs, mainly, RF.

**Key points**

- Assess respiratory risk in surgical patients in Catalonia (ARISCAT) scoring is a simplified and widely available risk score.
- ARISCAT is robust on predicting postoperative pulmonary complications in major abdominal surgeries.

## 2 | METHODS

### 2.1 | Patients

The cross-sectional study was performed on cancer patients who were candidates for elective major abdominal surgery in a tertiary hospital affiliated with Tehran university of medical sciences from March to October 2019. The tumors were resectable without distant metastasis; but, colon cancer patients with oligo metastasis to lung or liver were included. Medical consult was done to determine the risk of PPCs upon surgeon request. Senior pulmonologist consultant selected and recruited the patients. She was independent to the study assessment and clinical care.

Exclusion criteria were age <18 years, pregnancy and surgical interventions during pregnancy, interventions with local or peripheral anesthesia, surgery to treat complications of previous surgery, surgeries with a hospital stay of less than 24 h, and inability to perform CPET. Patients with PPCs due to vascular thrombosis and those with underlying pulmonary disease were excluded. The enrolled patients did not receive neoadjuvant chemotherapy.

## 2.2 | Sample size

The sensitivity of ARISCAT score is about 70% and the sensitivity of exercise test is about 90% in predicting the occurrence of PPCs. Considering the following formula and parameters, the sample size was estimated to be 70 by considering drop-out rate.

$$n = 2\frac{\left(z_{1-\frac{\alpha}{2}} + z_{1-\beta}\right)^2 \overline{p}\overline{q}}{(p_1 - p_2)^2}$$

| | | | |
|---|---|---|---|
| alfa= | 0/05 | $Z_{1-a/2}$= | 1/961150826 |
| Beta= | 0/2 | $Z_{1-B}$= | 0/841623031 |
| p1= | 0/9 | $\overline{p}$ = | 0/8 |
| p2= | 0/7 | n= | 63 |

## 2.3 | Procedure

Patients were assessed by ARISCAT risk score. The ARISCAT score calculates the risk of pulmonary complications by considering age, the site and duration of surgery, urgency of surgery, blood oxygen level, hemoglobin level, and history of respiratory infection in the last month. Based on these points, the risk is estimated to be low, moderate, or severe. The score was measured by a single assessor who was not blinded to the study at the time of medical consult. The consult was performed 5–7 days before planned surgery.

In the next step, CPET was performed to determine the risk of PPCs. Wasserman continuously increasing ramp exercise protocol was used.[18] Exercise tests were performed on Bicycle ergometer. Stress test was performed 2 days before operation. A single respiratory technician performed the test who was blinded to the study but the supervising pulmonologist was dependent to the study. During exercise, oxygen consumption ($VO_2$), $VO_{2max}$ or $VO_2$ peak, $Co_2$ production ($V_{Co2}$), and ventilation ($V_E$) were measured and the risk was determined based on the exercise test parameters; especially $VO_{2max}$ or $VO_2$ peak (whichever, the patient was attained). Respiratory exchange ratio (RER) was used to determine anaerobic threshold (AT) ($VO_2$ when RER equals one). After surgery, the patients were followed for 72 h to check if any RF occurred. RF was defined as hypoxemia $PaO_2 < 60$ mmHg and/or $PaCo_2 > 50$ mmHg, intensive care unit (ICU) admission, unplanned intubation, or prolonged ICU stay due to pulmonary complications. Finally, the concordance between ARISCAT score and CPET values in determining PPCs was assessed.

## 2.4 | Data analysis

The normality of quantitative data distribution was investigated using Kolmogorov–Smirnov test and graphical methods. Quantitative variables were described as mean (standard deviation [SD]) or median (interquartile range [IQR]) and qualitative variables were described as number (percentage). Two-sided *t*-test (or Mann–Whitney test) was used to compare quantitative variables between RF and non-RF patients and $\chi^2$ test (or Fisher-specific test) was used to compare qualitative variables between the two groups.

Spearman's correlation coefficient was calculated to examine the correlation between quantitative data of $VO_2$ and ARISCAT criteria. The cut-off point, sensitivity, and specificity of the predictive parameters of RF were calculated using the ROC (receiver operating characteristics) curve. The level of validity of each of the mentioned parameters was calculated by calculating the Youden's *J* statistic (sensitivity + specificity). To examine the agreement between the risk levels based on the two criteria of $VO_2$ and ARISCAT, the percentage of agreement and the $\varkappa$ coefficient of the given weight were calculated. *p* Value less than 0.05 was considered significant. All statistical analyzes were performed using SPSS software version 24 and Stata version 14.

## 3 | RESULTS

After screening the patients who needed medical consult upon surgeon request, 93 patients recruited and selected. Nine patients did not consent to perform CPET and 22 subjects were unable to do stress test. Finally, 62 subjects, including 23 women (37.1%) and 39 men (62.9%) with a mean (SD) age of 52 ± 15 years were evaluated, where 19 (30.6%) of them developed RF within 72 h of postoperative period. In terms of type of surgery, 32 patients (51.6%), 12 patients (19.4%), 11 patients (17.7%), and 7 patients (11.3%) underwent gastrointestinal (GI), pancreato-biliary, colorectal, and urological surgeries, respectively. All surgeries were open and done via midline laparotomy.

The characteristics of the subjects in terms of developing RF are listed in Table 1. As seen in Table 1, the observed difference in age and sex between the two groups of RF and non-RF patients was not statistically significant ($p > 0.05$). The proportion of patients undergoing GI surgeries was higher in RF group than in the non-RF group ($p = 0.01$).

Table 2 compared the status of predictor variables in terms of pulmonary complications (RF or non-RF). As can be seen in Table 2, the levels of $VO_2$ and AT were lower in patients developed RF and the observed difference was statistically significant ($p < 0.05$). ARISCAT risk score was higher in patients with RF ($p < 0.001$). $V_E/V_{CO2}$ levels were found to be higher in patients with RF but the observed difference was not statistically significant ($p = 0.24$).

The cut-off point, sensitivity, and specificity of each of the predictors of RF were calculated based on the ROC curve. All parameters including $VO_2$, ARISCAT score, and AT can predict RF ($p < 0.05$). Of these parameters, ARISCAT score showed the highest sensitivity (100%) and the highest specificity (90.5%) compared with other parameters (Youden's *J* statistic = 0.905). The $VO_2$ parameter showed the highest validity (Youden's *J* statistic = 0.747).

The relationship between the subgroups of each of the predictive parameters and RF status of patients were examined. According to

**TABLE 1** Characteristics of the subjects according to respiratory failure diagnosis.

| | | RF diagnosis | | |
|---|---|---|---|---|
| | | No ($n$ = 43) | Yes ($n$ = 19) | $p$ Value |
| Age, year, median (IQR) | | 52 (35–58) | 57 (51–62) | 0.13 |
| Sex, F/M | | 17/26 | 6/13 | 0.55 |
| Surgery kind, $n$ (%) | Gastrointestinal cancer | 18 (41.9) | 14 (73.7) | 0.01[a] |
| Average ARISCAT score (As) | As:46 | | | |
| | Pancreato-biliary cancer | 9 (20.9) | 3 (15.8) | |
| | As:41 | | | |
| | Colorectal cancer | 9 (20.9) | 2 (10.5) | |
| | As:36 | | | |
| | Urological cancer | 7 (16.3) | 0 (0) | |
| | As:19 | | | |

Abbreviation: ARISCAT, assess respiratory risk in surgical patients in Catalonia.
[a]Gastrointestinal versus other abdominal surgery.

**TABLE 2** Mean (interquartile range) of predictors by incidence of respiratory failure.

| | RF group | | |
|---|---|---|---|
| Predictors | No ($n$ = 43) | Yes ($n$ = 19) | $p$ Value |
| $VO_2$, mL/kg/min | 16.8 (14.58–20.03) | 11.9 (9.2–15) | <0.001 |
| ARISCAT | 38 (26.5–41.25) | 52 (48–68) | <0.001 |
| $V_E/V_{CO2}$ | 32 (29.42–37.69) | 35 (29.5–39) | 0.24 |
| AT, mL/kg/min | 13 (9.9–14.55) | 10.15 (8.08–12) | 0.04 |

Abbreviations: ARISCAT, assess respiratory risk in surgical patients in Catalonia; AT, anaerobic threshold.

$VO_2$ and ARISCAT score, with increasing score and trend from low to medium and high status, the probability of RF increased, and the observed correlation was statistically significant ($p < 0.05$; Table 3). The relationship of $V_E/V_{CO2}$ and AT parameters with RF status was not statistically significant ($p > 0.05$).

Medium (IQR), RCI parameter was higher in RF group than the other group and the observed difference was statistically significant ($p < 0.001$). Spearman's correlation coefficient between quantitative measurements of $VO_2$ and ARISCAT score was equal to −0.43 ($p < 0.001$), which indicates an inverse and mean correlation (Figure 1).

Before surgery according to $VO_2$ index, 21 (33.9%), 27 (43.5%), and 14 (22.6%) of the subjects were in low, medium, and high-risk groups, respectively. Regarding ARISCAT score, 12 (19.4%), 30 (48.4%), and 20 (32.2%) of the subjects were found to be in low, medium, and high-risk groups, respectively (Table 3 and Figure 2). The percentage of agreement between different subgroups (low, medium, and high) of the two indices ($VO_2$ and ARISCAT score) was equal to 81.45% ($p < 0.001$) and the $\kappa$ coefficient of the given weight was equal to 0.54 ($p < 0.001$), indicating a good agreement between these two criteria.

**TABLE 3** Relationship between predictive parameters and RF status.

| | | RF status | | |
|---|---|---|---|---|
| | | No ($n$ = 43) | Yes ($n$ = 19) | $p$ Value |
| $VO_2$, $n$ (%) | Low[a] | 20 (95.2) | 1 (4.8) | <0.001 |
| | Moderate[b] | 20 (74.1) | 7 (25.9) | |
| | High[c] | 3 (21.4) | 11 (78.6) | |
| ARISCAT, $n$ (%) | Low[d] | 12 (100) | 0 (0) | <0.001 |
| | Moderate[e] | 29 (96.7) | 1 (3.3) | |
| | High[f] | 2 (10) | 18 (90) | |

Abbreviation: ARISCAT, assess respiratory risk in surgical patients in Catalonia.
[a]$VO_2$ > 19 mL/kg/min.
[b]$VO_2$ 11–19 mL/kg/min.
[c]$VO_2$ < 11 mL/kg/min.
[d]Numbers of points in risk score <26.
[e]Numbers of points in risk score 26–44.
[f]Numbers of points in risk score >44.

## 4 | DISCUSSION

The goal of this study was to explore the correlation between preoperative CPET values and ARISCAT score in prediction of PPCs in major abdominal surgeries in a tertiary cancer care hospital. The results showed that probability of RF according to ARISCAT score increased with increasing score and status trend from low to medium and high, indicating a favorable predictive power of this test, which is in line with Kara et al. in 2020; they reported that this score had a high predictive value in the evaluation of complications after upper and lower abdominal surgeries.[19] A prospective and observational study was conducted in 2020 in Saint John Hospital by Gupta et al. on 1170 patients undergoing noncardiac surgery. Patients were evaluated by ARISCAT criteria, and complications and length of hospital stay were also evaluated. Postoperative pulmonary complications were reported in 5% of patients and the results revealed that patients with high and moderate risk in the test were more likely to have complications. Old age, the presence of the nasogastric tube, and PPCs were considered as independent risk factors associated with PPC. In this study, ARISCAT criterion is a suitable criterion for estimating high risk cases.[20]

However, there are conflicting results about the power of ARISCAT in risk prediction of PPCs in certain patient populations. Fernandes et al. investigated ARISCAT risk score and alternate tools

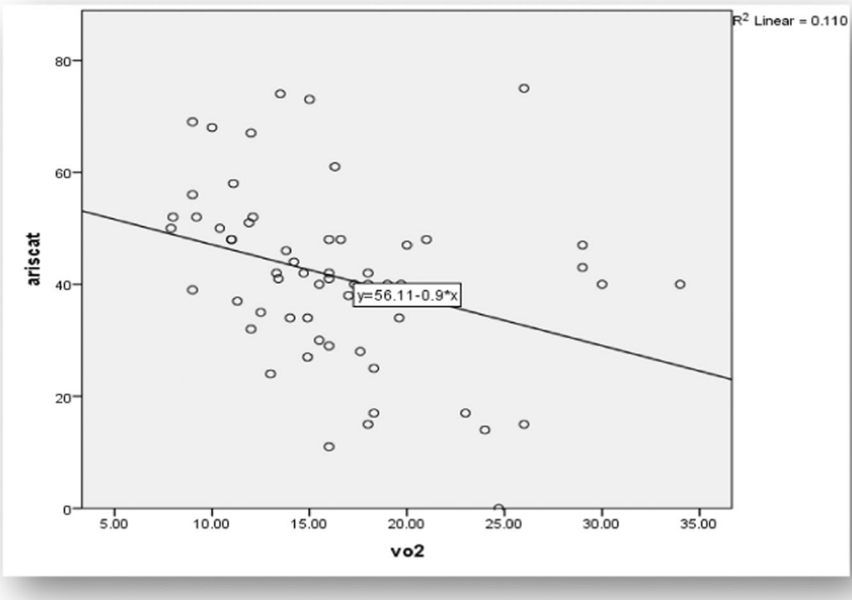


**FIGURE 1** Distribution diagram and regression risk between $VO_2$ and ARISCAT criteria. ARISCAT, assess respiratory risk in surgical patients in Catalonia.

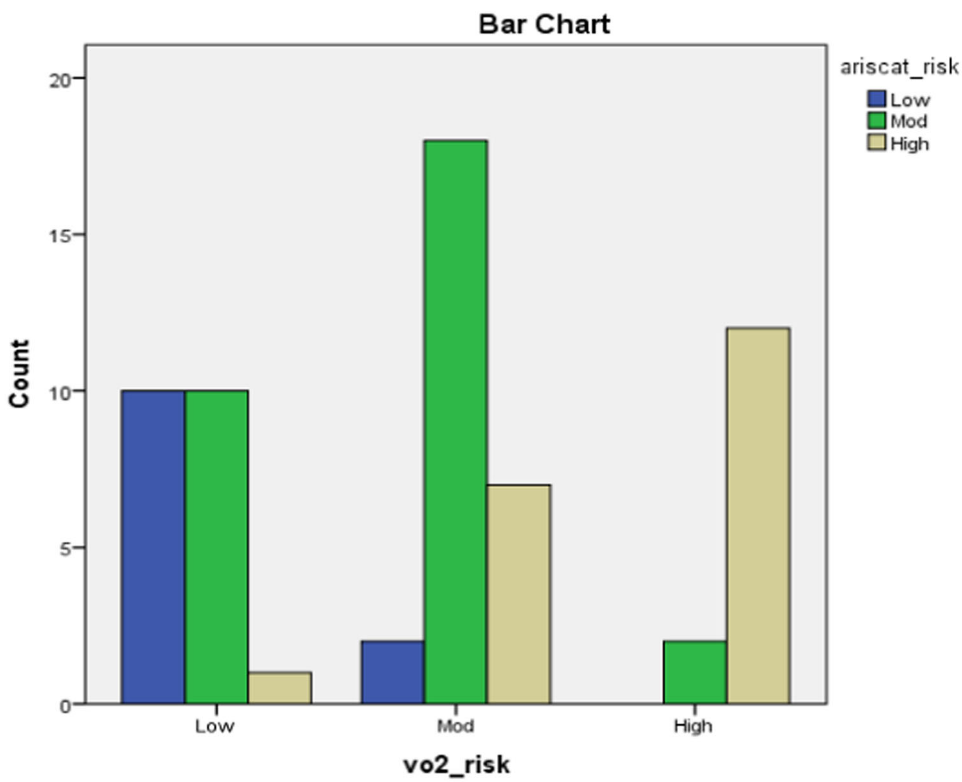


**FIGURE 2** Bar chart comparing ARISCAT benchmark subgroups by status of $VO_2$ subgroups. ARISCAT, assess respiratory risk in surgical patients in Catalonia.

in prediction of PPCs in 341 digestive cancer surgical patients. They found that there was no superiority around use of a particular tool and proposed a new scoring which may be more helpful in discriminating patients at high risk of developing PPCs.[21] In 2019, Wood et al. performed a retrospective study on 794 patients with head and neck surgery and showed both ARISCAT and Gupta pulmonary risk scores were not accurate in prediction of PPC in this oncosurgical patients.[22] Systemic inflammation, nutritional deficit, sarcopenia, seen more commonly in elderly and cancer patients could comprise postoperative period and increase the chance of PPCs occurrence. In 2023, Liu et al. developed a machine-learning based algorithm to predict PPCs in elderly surgical patients. The constructed model included age, oxygen saturation, ANS (the albumin/neutrophil to lymphocyte ratio score), duration of surgery, and blood transfusion. Their study showed the new model is superior to ARISCAT in prediction of PPCs.[23] It is not clear if preoperative cardiovascular and muscular endurance and CPET values such as $VO_2$ would affect the incidence of PPCs. Values from CPETS are well recognized for their discriminating ability to define high risk lung cancer patients undergoing thoracic surgeries.[24] Exercise tests are less frequently used in preoperative evaluation of cancer patients undergoing major abdominal surgeries. Therefore, in the present study, it was aimed to assess the correlation of ARISCAT score and CPET values mainly $VO_2$ in risk prediction of PPCs. The results showed that ARISCAT score, $VO_2$, and AT were able to predict the occurrence of RF. Among these parameters, ARISCAT showed both the highest sensitivity (100%) and the highest specificity (90.5%) followed by the $VO_2$ value. The ARISCAT score does not include indices of cardiovascular and muscular endurance such as $VO_2$. Therefore, it was assumed that ARISCAT could not accurately predict the risk of PPCs in cancer patients. But the results of this present study showed that ARISCAT is a valuable and highly sensitive prediction tool and there is great concordance between the score and CPET values in prediction of PPCs. CPET is a sophisticated exercise test that is not widely accessible in many care centers. On the other hand, cancer surgical candidates may be unable to perform the test because of their fragility. The existing limits for exercise test along with simplicity, accessibility, and accuracy of ARISCAT score makes it the most popular tools in prediction of PPCS even in cancer patients.

In the present study, there were limits. The sample size was not large. Subjects were heterogeneous regarding the type of cancer and surgery. The subjects were followed for a short period of time so concordance of ARISCAT and CPET could not be investigated in predicting long term mortality and morbidity due to PPCs. Further studies with less heterogeneity in subjects, large samples and longer follow-up are needed.

## 5 | CONCLUSION

According to the results of this study, both $VO_2$ and ARISCAT score predict the probability of RF occurrence. But, ARISCAT showed both the highest sensitivity (100%) and the highest specificity (90.5%) when compared with CPET values. CPET is not widely available in all health care centers, but ARISCAT score can be easily and quickly calculated with a powerful accuracy in risk prediction. These features make the test the most efficient and practical prediction tool among other risk prediction tools.

### AUTHOR CONTRIBUTIONS

**Somaye Rezaian**: Conceptualization; data curation; formal analysis; investigation; resources; software; writing—original draft; writing—review and editing. **Mehrnaz Asadi Gharabaghi**: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing—original draft; writing—review and editing. **Besharat Rahimi**: Resources; supervision. **Marsa Gholamzadeh**: Data curation; investigation; methodology; writing—original draft; writing—review and editing.

### CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

### DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available upon request.

### ETHICS STATEMENT

All patients' information was confidential. Ethical declarations of the Helsinki and Ethics Research Committees affiliated with Tehran University of Medical Sciences were considered. The study was conducted after approval by the Research Council of the Medical School and receiving the code of ethics (IR.TUMS.IKHC.REC.1396.4868). The patients were informed about study aims and design. The risks of stress test were described for them. The consulting pulmonologist communicated the patients and obtained informed consent.

### TRANSPARENCY STATEMENT

The lead author Mehrnaz Asadi Gharabaghi affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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