

Why should we perform pulmonary function test before coronary artery bypass grafting?

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ABSTRACT

Objectives: In this study, we aimed to examine the relationship between preoperative pulmonary function test (PFT) parameters and postoperative length of invasive mechanical ventilation (IMV), length of intensive care unit (ICU) and hospital stay in patients who underwent coronary artery bypass grafting (CABG).

Patients and methods: Between October 2017 and July 2018, a total of 100 patients (84 males, 16 females; mean age: 61.1±10.0 years; range, 41 to 85 years) who underwent elective CABG surgery for the first time and who did not have any additional cardiac problems, except for coronary artery disease, had an ejection fraction (EF) of ≥30% and underwent preoperative PFTs were retrospectively analyzed. The percent forced vital capacity (FVC %) predicted from the PFT values and percent forced expiratory volume in 1 sec (FEV₁%) were recorded. An IMV duration of ≤12 h was considered normal and >12 h was considered prolonged. A length of ICU stay for ≤24 h was considered normal and >24 h was considered prolonged. A length of hospital stay for ≤7 days was considered normal and >7 was considered prolonged.

Results: As the predicted FVC (%) value decreased in the preoperative PFTs, the length of IMV, length of ICU and hospital stay increased significantly (p=0.040, p=0.036, p=0.009, respectively). In terms of the predicted FEV₁ (%) value, as the predicted FEV₁ (%) value decreased, the duration of IMV, length of ICU and hospital stay prolonged (p=0.023, p=0.044, p=0.024, respectively).

Conclusion: It is possible to have an idea about postoperative duration of ventilation, ICU and hospital stay based on PFT parameters. Also, the result would be more realistic when adapted to existing scoring systems to assess postoperative complications. Therefore, we believe that scoring systems for evaluating complications after cardiac surgery should include not only chronic lung disease, but also PFT parameters that give a more detailed information.

Keywords: Coronary artery bypass grafting, intensive care unit, pulmonary function test.

Coronary artery bypass grafting (CABG), which was first applied in the 1960s, is still a valuable and effective treatment method in the treatment of coronary artery diseases.^[1] However, postoperative pulmonary complications such as atelectasis, respiratory failure, and respiratory tract infections that may develop after open heart surgery are the facts we encounter in our daily practice.^[2]

Factors such as median sternotomy, hypothermia applied to protect the myocardium, pleurotomy and internal mammary artery dissection can have a negative effect on lung functions in the postoperative period.^[2,3] Besides, CABG disrupts alveolar stability by creating changes in complement system activation, neutrophil increase in the pulmonary vascular bed, formation of free oxygen radicals and alveolar surfactant production.^[4] It is inevitable that atelectasis

would develop as a result of changes in the amount of alveolar surfactant and a decrease in alveolar stability. Physiological shunts occur in patients during this period and the alveolo-arterial oxygen gradient increases.^[5] Pulmonary complications may occur as a result of all them, leading to a serious cost increase by extending the need for intensive care unit (ICU) and the length of hospital stay.^[6]

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In scoring systems that are widely used to assess preoperative cardiac surgery risk (Japan Cardiac Operative Risk Assessment System [JapanSCORE], the Society of Thoracic Surgeons [STS] risk model, and the European Cardiac Risk Assessment System [EuroSCORE II], it is roughly questioned whether there is chronic lung disease. Pulmonary function test (PFT) parameters, which is a very easily applicable and accessible method, are not included in any of these scoring systems.^[7] However, the need for postoperative ICU and pulmonary complications that may arise can be predicted by the results of PFT in the preoperative period.^[8]

In the present study, we aimed to examine the relationship between preoperative PFT parameters and postoperative duration of ventilation, ICU and hospitalization stay.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at University of Health Sciences, Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital, Department of Cardiovascular Surgery between October 2017 and July 2018. A total of 100 patients (84 males, 16 females; mean age: 61.1 ± 10.0 years; range, 41 to 85 years) who underwent elective CABG surgery for the first time and who did not have any additional cardiac problems, except for coronary artery disease, had an ejection fraction (EF) of $\geq 30\%$ and underwent preoperative PFTs were included in the study. The PFT was applied to all patients by the traditional method who were scheduled for elective CABG in our hospital. There was no difference between the patients in terms of anesthesia technique or sedative medication. Predicted forced vital capacity percentage (FVC%) and forced expiratory volume in 1 sec percentage (FEV₁%) were recorded. Patients records were obtained from the hospital database. A written informed consent was obtained from each patient. The study protocol was approved by the Istanbul Yedikule Chest Diseases and Thoracic Surgery Training and Research Hospital Clinical Research Ethics Committee (No: 2021-121). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patients who were taken to ICU with intra-aortic balloon pump (IABP), extracorporeal membrane oxygenation (ECMO) support devices after the operation, patients who had prolonged ICU stay due

to reasons other than respiratory functions during ICU follow-up, patients who were re-transferred to the ICU during hospitalization for non-respiratory reasons and patients with prolonged hospitalization due to reasons other than respiratory functions were excluded from the study. The following parameters were considered in the assessment of data:

- An invasive mechanical ventilation (IMV) duration of ≤ 12 h was considered normal and >12 h was considered prolonged.
- A length of ICU stay of ≤ 24 h was considered normal, >24 h is prolonged.
- For the total hospitalization (ICU + ward), a length of stay for ≤ 7 days was considered normal and >7 days was considered prolonged.

Operation technique

All patients were operated electively. By performing a median sternotomy, arterial cannulation from the ascending aorta and venous cannulation from the right atrium with a two-stage venous cannula was connected to a cardiopulmonary bypass (CPB) device. Moderate hypothermia (28°C) was achieved, cardiac arrest was achieved with 10 to 15 mL/kg cold blood cardioplegia or 5 mL/kg cold crystalloid cardioplegia (St. Thomas II) after insertion of the aortic cross-clamp. After the surgical procedure, reperfusion was achieved with 5 mL/kg warm blood cardioplegia before the cross-clamp was removed. A roller head pump and hollow fiber membrane oxygenator were used in the CPB device. Left internal mammary artery (LIMA) and saphenous vein were used as the graft in all patients.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean \pm standard deviation (SD) or median (interquartile range [IQR]), while categorical variables were expressed in number and frequency. The compliance with the normality assumption was tested using the Kolmogorov-Smirnov test. In examining the difference between categorical variables with two groups, the independent samples t-test was used for variables suitable for the assumption of normality, and the Mann-Whitney U test was used for variables not compatible with the assumption of normality. The chi-square test was used to examine the relationship between two categorical variables. A *p* value of <0.05 was considered statistically significant.

RESULTS

Of the patients, 72 had a normal weight (body mass index [BMI] <30 kg/m²) and 28 had obesity (BMI ≥ 30 kg/m²). The mean EF value was $52.6 \pm 8.5\%$. The mean operation time of the patients was 283.0 ± 75.6 min, the mean aortic clamp time was 78.1 ± 52.2 min, and the mean CPB time was 118.0 ± 60.7 min. The mean predicted FEV₁ (%) and FVC (%) values were $90.1 \pm 19.4\%$ and $83.1 \pm 19.9\%$, respectively (Table 1).

The mean preoperative laboratory test values and chronic disease status of the patients are shown in

Table 2 and Table 3, respectively. None of the patients received blood products and inotropic support in the preoperative period.

Six patients died during the 12-month follow-up period after the operation, 94 of them were still alive. Among deceased patients, the predicted FEV₁ (%) value was $88.3 \pm 26.5\%$. Among survivors, this value was $90.3 \pm 19.0\%$, indicating no statistically difference ($p=0.816$). The median predicted FVC values were 74.80 (IQR: 70.88-93.66) for non-survivors and 84.10 (IQR: 71.00-93.60) for survivors ($p=0.701$). Although there was no statistically significant difference, predicted FVC values of survivors were higher.

Table 1
Demographic and baseline characteristics of patients

	n	Mean \pm SD
Age (year)		61.1 \pm 10.0
Sex		
Male	84	
BMI (kg/m ²)		
<30	72	
≥ 30	28	
IMV stay (h)		
≤ 12	82	
>12	18	
ICU stay (h)		
≤ 24	73	
>24	27	
Total hospital stay (days)		
≤ 7	68	
>7	32	
Procedures done		
CABGx1	4	
CABGx2	28	
CABGx3	45	
CABGx4	19	
CABGx5	4	
Operative time (min)	100	283.0 \pm 75.6
Aortic clamping time (min)	100	78.1 \pm 52.2
Cardiopulmonary bypass time (min)	100	117.950 \pm 60.68
Left ventricular ejection fraction (%)	100	52.550 \pm 8.54
Predicted FVC (%)	100	83.132 \pm 19.91
Predicted FEV ₁ (%)	100	90.137 \pm 19.40
Mortality*		
Yes	6	
No	94	

SD: Standard deviation; BMI: Body mass index; IMV: Invasive mechanical ventilation; ICU: Intensive care unit; CABG: Coronary artery bypass grafting; FVC: Forced vital capacity; FEV1: Forced expiratory volume in 1 sec. * At postoperative 12 months.

Table 2
The mean preoperative laboratory test results

	Mean±SD
WBC (μg/L)	9.2±3.5
HGB (g/dL)	13.7±1.5
HCT (%)	40.5±4.5
Platelet (μg/dL)	252.3±3.1
Creatine (mg/dL)	0.9±0.2
Urea (mg/dL)	18.1±6.8
AST (u/L)	24.2±17.3
ALT (u/L)	27.2±14.7

SD: Standard deviation; WBC: White blood cell; HGB: Hemoglobin; HCT: Hematocrit; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase.

Table 3
Preoperative chronic disease status of patients

	n
None	28
DM	23
HT	29
COPD	6
DM + HT	11
DM + COPD	1
HT + COPD	1
DM + HT + COPD	1
Total	100

DM: Diabetes mellitus; HT: Hypertension; COPD: Chronic Obstructive Pulmonary Disease.

Duration of ventilation: The relationship between PFT parameters and duration of IMV was evaluated. Accordingly, the median predicted FVC (%) value of the patients with prolonged IMV duration was 64.00 (IQR: 58.20-90.90), while the median predicted FVC (%) value of the patients with normal IMV duration was 85.00 (IQR: 74.30-93.95) ($p=0.040$) (Figure 1a). The mean predicted FEV₁ (%) value of the patients with prolonged IMV duration was 82.1±22.5, while the mean predicted FEV₁ (%) value of the patients with normal IMV duration was 92.5±17.8 ($p=0.023$) (Figure 1b).

- The median predicted FVC (%) value of patients with prolonged IMV duration is 64.00 (IQR: 58.20-90.90), the median predicted FVC (%) value of patients with normal

IMV duration is 85.00 (IQR: 74.30-93.95) ($p=0.040$) (Figure 1a).

- The mean predicted FEV₁ (%) value of patients with prolonged IMV duration is 82.1±22.5, the mean predicted FEV₁ (%) value of patients with normal IMV duration is 92.5±17.8 ($p=0.023$) (Figure 1b).

The patients with low predicted FEV₁% and predicted FVC% values had have statistically significantly longer IMV.

- When the predicted FEV₁ (%) was divided into two groups as ≥ 80 and $<80\%$, the duration of IMV was found as follows: in patients with predicted FEV₁ (%) $\geq 80\%$, the IMV duration was normal in 57 patients, while

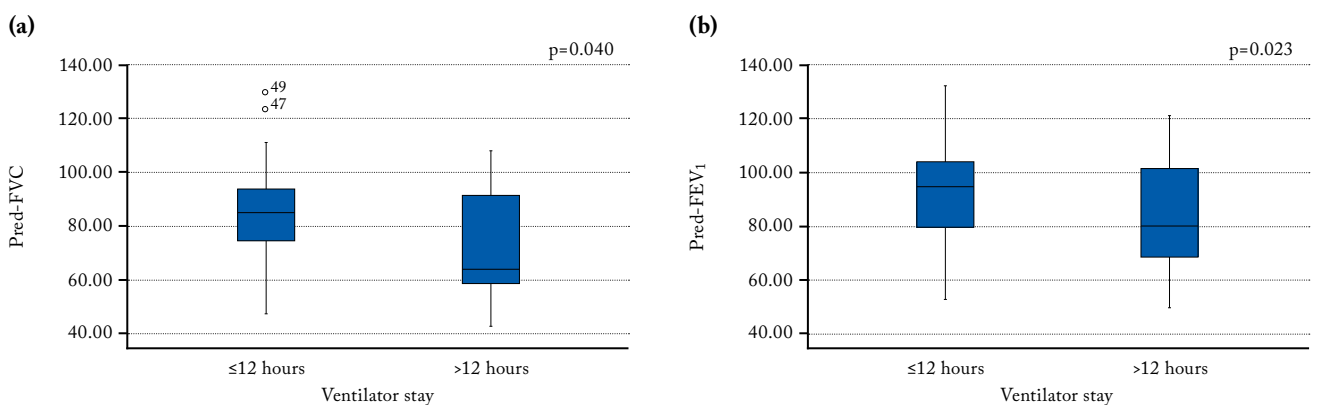


Figure 1. (a) Relationship between IMV and predicted FVC (%). **(b)** Relationship between IMV and predicted FEV₁ (%).

IMV: Invasive mechanical ventilation; FVC: Forced vital capacity; FEV₁: Forced expiratory volume in 1 sec.

it was prolonged in 11 patients. In patients with predicted FEV₁ (%) <80%, the IMV duration was normal in 20 patients, while it was prolonged in 12 patients ($p=0.035$) (Figure 2a). In patients with predicted FEV₁ (%) $\geq 80\%$, the IMV duration was normal in 57 patients, while it was prolonged in 11 patients.

- In patients with predicted FEV₁ (%) <80%, the IMV duration was normal in 20 patients, while it was prolonged in 12 patients ($p=0.035$) (Figure 2a).
- *ICU stay:* The relationship between PFT parameters and duration of ICU was examined. Accordingly, the median predicted FVC (%) value of the patients with prolonged ICU duration was 72.65 (IQR: 58.42-93.30), while the median predicted FVC (%) value of the patients with normal IMV duration was 81.10 (IQR: 74.90-94.13) ($p=0.036$) (Figure 3a). The mean predicted FEV₁ (%) value of the patients with prolonged ICU duration was 82.3 ± 22.0 , while the mean predicted FEV₁ (%) value of the patients with normal ICU duration was 93.2 ± 17.5 ($p=0.024$) (Figure 3b). The median predicted FVC (%) value of patients with prolonged ICU duration is 72.65 (IQR: 58.42-93.30), the median predicted FVC (%) value of patients with normal IMV duration is 81.10 (IQR: 74.90-94.13) ($p=0.036$) (Figure 3a).
- The mean predicted FEV₁ (%) value of patients with prolonged ICU duration is 82.3 ± 22.0 , the mean predicted FEV₁ (%) value of patients with normal ICU duration is 93.2 ± 17.5 ($p=0.024$) (Figure 3b).

The patients with low predicted FEV₁% and predicted FVC% values had statistically significantly longer ICU stay.

- When the predicted FEV₁ (%) was divided into two groups as ≥ 80 and <80%, the duration of ICU stay was found as follows: in patients with predicted FEV₁ (%) $\geq 80\%$, the IMV duration was normal in 54 patients, while it was prolonged in 14 patients. In patients with predicted FEV₁ (%) <80%, the IMV duration was normal in 18 patients, while it was prolonged in 14 patients ($p=0.030$) (Figure 2b). In patients with predicted FEV₁ (%) $\geq 80\%$, the IMV duration was normal

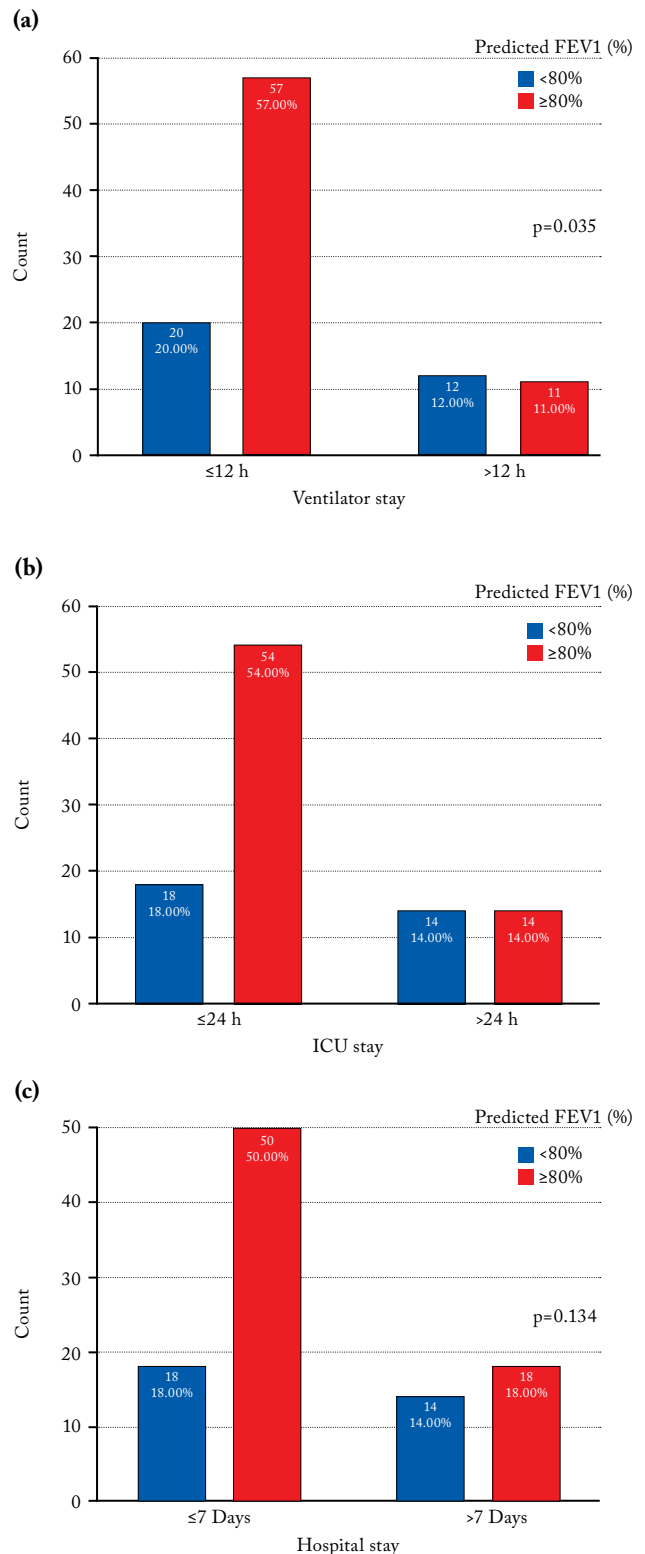


Figure 2. Relationship between ventilator, ICU and hospital stay in patients with predicted FEV₁ (%) ≥ 80 and <80%. FEV₁: Forced expiratory volume in 1 sec.

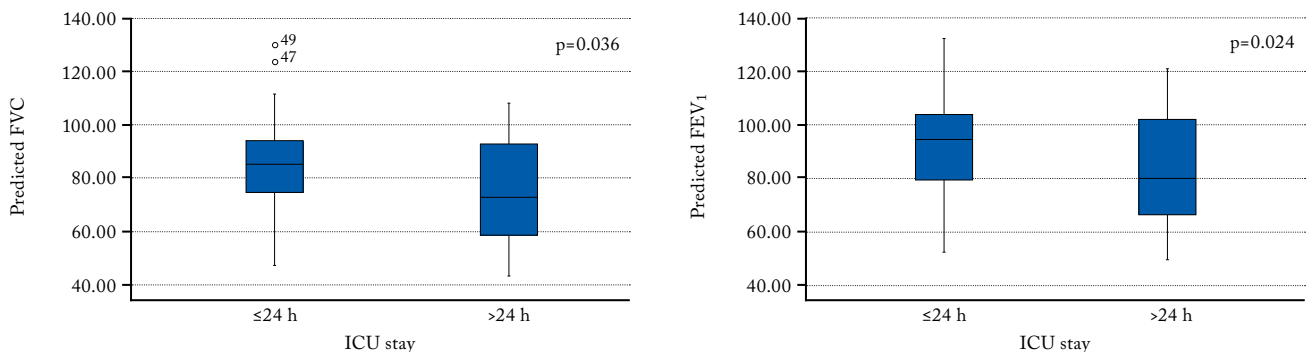


Figure 3. (a) Relationship between ICU stay and predicted FVC (%). **(b)** Relationship between ICU stay and predicted FEV₁ (%). ICU: Intensive care unit; FVC: Forced vital capacity; FEV₁: Forced expiratory volume in 1 sec.

in 54 patients, while it was prolonged in 14 patients.

- In patients with predicted FEV₁ (%) <80%, the IMV duration was normal in 18 patients, while it was prolonged in 14 patients ($p=0.030$) (Figure 2b).

Hospital stay

The relationship between PFT parameters and duration of hospitalization was examined. Accordingly, the median predicted FVC (%) value of the patients with prolonged duration of hospitalization was 81.65 (IQR: 59.33-88.85), while the median predicted FVC (%) value of the patients with normal duration of hospitalization was 86.50 (IQR: 73.36-96.45) ($p=0.009$) (Figure 4a). The median predicted FEV₁ (%) value of the patients with prolonged duration of

hospitalization was 85.95 (IQR: 70.15-85.95), while the median predicted FEV₁ (%) value of the patients with normal duration of hospitalization was 92.15 (IQR: 79.60-92.15) ($p=0.044$) (Figure 4b).

- The median predicted FVC (%) value of patients with prolonged duration of hospitalization is 81.65 (IQR: 59.33-88.85), the median predicted FVC (%) value of patients with normal duration of hospitalization is 86.50 (IQR: 73.36-96.45) ($p=0.009$) (Figure 4a).
- The median predicted FEV₁ (%) value of patients with prolonged duration of hospitalization is 85.95 (IQR: 70.15-85.95), the median predicted FEV₁ (%) value of patients with normal duration of hospitalization is 92.15 (IQR: 79.60-92.15) ($p=0.044$) (Figure 4b).

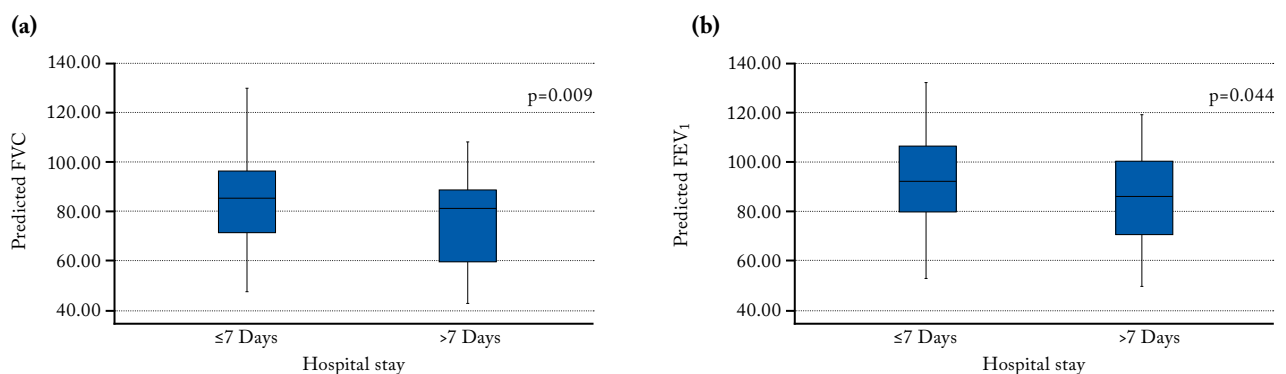


Figure 4. (a) Relationship between hospital stay and predicted FVC (%). **(b)** Relationship between hospital stay and predicted FEV₁ (%).

FVC: Forced vital capacity; FEV₁: Forced expiratory volume in 1 sec.

The patients with low predicted FEV₁% and predicted FVC% values had statistically significantly longer hospitalization stay.

- When the predicted FEV₁ (%) was divided into two groups as ≥ 80 and < 80 %, the duration of IMV was found as follows: in patients with predicted FEV₁ (%) ≥ 80 %, the hospitalization stay duration was normal in 50 patients, while it was prolonged in 18 patients. In patients with predicted FEV₁ (%) < 80 %, the hospitalization stay duration was normal in 18 patients, while it was prolonged in 14 patients ($p=0.134$) (Figure 2c). In patients with predicted FEV₁ (%) ≥ 80 %, the hospitalization stay duration was normal in 50 patients, while it was prolonged in 18 patients.
- In patients with predicted FEV₁ (%) < 80 %, the hospitalization stay duration was normal in 18 patients, while it was prolonged in 14 patients ($p=0.134$) (Figure 2c).

DISCUSSION

In the present study, the relationship between predicted FEV₁ (%) and predicted FVC (%) values and duration of ventilation, length of ICU and hospital stay was examined. According to the results, as the preoperative predicted FEV₁ (%) and predicted FVC (%) values decreased, the duration of ventilation, length of ICU and hospital stay statistically significantly increased.

In a study, Alam et al.^[8] showed that predicted FEV₁ (%) and FVC (%) were good predictors of postoperative pulmonary complications (e.g., respiratory failure, atelectasis, and pulmonary infections). In the aforementioned study, as the rate of predicted FEV₁ (%) decreased, the rate of respiratory failure and atelectasis increased ($p=0.003$ vs. $p<0.001$, respectively).

An initial decrease of 40 to 50% in FEV₁ (%) and FVC (%) values on the first and third days after CABG is expected.^[9,10] There is a study showing that there is a significant decrease in FEV₁ (%) and FVC (%) values in three-year follow-ups of PFT parameters in patients with CABG compared to the preoperative period.^[11] Therefore, in patients with low FEV₁ (%) in the preoperative period, a greater reduction in FEV₁ (%) and hypoxia in the postoperative period would be inevitable. In our study, when we divided

and examined patients into two groups as predicted FEV₁ (%) ≥ 80 % and predicted FEV₁ (%) < 80 %, the group with predicted FEV₁ ≥ 80 % had a shorter ICU stay and ventilation duration than those with predicted FEV₁ < 80 % ($p=0.030$ and $p=0.035$, respectively). However, there was no statistically difference between the two groups in terms of length of hospital stay ($p=0.134$).

In a study by Kshirsagar et al.,^[12] 370 patients who underwent CABG between the ages of 35 and 65 years, the duration of hospital stay increased significantly as FEV₁ (%) decreased. In another study by Saleh et al.^[13] including a large number of patients ($n=11,217$), the patients were divided into three groups according to the severity of chronic obstructive pulmonary disease (COPD) (FEV₁/FVC < 70 % and predicted FEV₁ ≥ 80 %: mild COPD; FEV₁/FVC < 70 % and ≤ 50 % predicted FEV₁ < 80 %: moderate COPD; and FEV₁/FVC < 70 % and ≤ 30 % predicted FEV₁ < 50 %: severe COPD). Accordingly, as the severity of COPD increased, many pulmonary disease complications such as inotropic support, acute renal failure, and early mortality increased significantly. Similar to our study, it was shown that there was a negative correlation between FEV₁ (%) and hospital stay. In another study by the aforementioned authors, a reduced FEV₁ (%) (odds ratio [OR]: 0.99; 95% confidence interval [CI]: 0.98-0.99) occurred in 1.96% of CABG patients which was a preoperative predictor of prolonged mechanical ventilation.^[14]

Prolonged duration of mechanical ventilation after CABG also extends the length of ICU and hospital stay. It is known to cause a decrease in early and mid-term survival.^[7] Hulzebos et al.^[15] suggested that preoperative pulmonary muscle physiotherapy could reduce postoperative hospital stay and the incidence of pulmonary complications. In a meta-analysis, the length of ICU stay and hospital stay could be reduced, particularly in elderly patients, with interventions in the preoperative period (e.g., inspiratory muscle physiotherapy, pulmonary exercise physiotherapy).

In the postoperative 12-month follow-up, although there was no statistically difference between the predicted FEV₁ (%) and FVC (%) values of the survivors and non-survivors, the median predicted FVC values of the survivors were higher than those with non-survivors. Patients with moderate and severe airway obstruction (FEV₁ / FVC < 70 % and FEV₁ (%) < 80 %) had a 3.2 times higher mortality than patients

without airway obstruction in the study of Adabag et al^[16] (95% CI: 1.6-6.2, $p=0.001$).

In the literature, it has been shown that EuroSCORE is the best scoring system that can predict 30-day and 12-month mortality after cardiac surgery.^[17] On the other hand, studies have been carried out on many different parameters that are thought to be missing in this scoring system.^[18] McAllister et al.^[19] created two scoring groups to determine mortality after cardiac surgery: (i) EuroSCORE and (ii) FEV₁ (%) values added to the EuroSCORE. As a result, the EuroSCORE scoring system with FEV₁ (%) values was more successful in predicting mortality.

The main limitations of this study include its single-center, retrospective design with a relatively small sample size. In addition, since the study design was retrospective, smoking history and biomass exposure affecting PFT parameters in the preoperative period could not be taken into account.

In conclusion, spirometry is an easily accessible, simple-to-use method that does not require serious costs and is used to evaluate the lung physiological reserve. It is possible to have an idea about postoperative durations of ventilation, ICU and hospital stay based on the PFT parameters. Also, the result would be more realistic when adapted to existing scoring systems to assess postoperative complications. Therefore, we believe that scoring systems for evaluating complications after cardiac surgery should include not only chronic lung disease, but also PFT parameters that give a more detailed information.

Declaration of conflicting interests

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