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## Respiratory pressures and expiratory peak flow rate of patients undergoing coronary artery bypass graft surgery

### Authors' Contribution:

- A** Study Design
- B** Data Collection
- C** Statistical Analysis
- D** Data Interpretation
- E** Manuscript Preparation
- F** Literature Search
- G** Funds Collection

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### Summary

#### Background:

To evaluate clinical and laboratorial parameters that predict decreased respiratory function in patients subjected to coronary artery bypass graft surgery (CABG).

#### Material/Methods:

This was a prospective study evaluating 61 patients subjected to CABG with cardiopulmonary bypass, median sternotomy, and under mechanical ventilation for up to 24 h. One day before surgery, clinical information was recorded. Maximal inspiratory (MIP) and expiratory (MEP) pressures, and expiratory peak flow rate (EPFR) values were assessed 1 day before surgery and on the fifth postoperative day. Student's *t* test, 2-way ANOVA, Pearson's linear correlation, and logistic regression were used for statistical analysis.

#### Results:

Patients were 63±10 years old, 67% males. Arterial hypertension was found in 75.4% of the patients, diabetes in 31.2%, dyslipidemia in 63.9%, tabagism in 25%, and chronic obstructive pulmonary disease (COPD) in 16.4%. Previous myocardial infarction was found in 67%. Preoperative hemoglobin levels were 12.8±1.71 g/dL. Older individuals had lower preoperative MEP and EPFR values. Preoperatively, positive association was found between hemoglobin levels and maximal respiratory pressures and EPFR values. Patients with both class III angina and COPD presented higher reductions in pulmonary pressures between the preoperative period and the 5<sup>th</sup> postoperative day.

#### Conclusions:

Older age and low hemoglobin levels are associated with preoperative low maximal respiratory pressures and EPFR. The combination of severe angina and COPD results in higher postoperative reduction of maximal respiratory pressures for patients who underwent CABG.

#### key words:

**coronary artery bypass graft • pre- and intra-operative factors • maximal inspiratory pressure • maximal expiratory pressure • expiratory peak flow rate**

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## BACKGROUND

Coronary artery disease (CAD) is the most common cause of death in the Western world. The treatment of CAD depends on the clinical picture, the results of provocative ischemia tests, the coronary lesions (degree, location and anatomy), the left ventricular function, and associated co-morbidities. Coronary artery bypass graft surgery (CABG) has been extensively used for CAD treatment, and is associated with a decrease of morbidity and mortality [1–4].

Because it is a major surgery involving the thoracic cavity, lung function is compromised in the postoperative period. Lung complications have been described as the main cause of heart surgery postoperative morbidity and mortality [5]. In patients with severe cardiac diseases, physical activity is often reduced, leading to decreased lung volumes and capacities, which are exacerbated by heart surgery [6,7].

In heart surgery, during the postoperative period, pulmonary complications are related to preoperative risk factors such as aging, smoking, poor nutritional status, associated co-morbidities, and previous lung diseases and altered lung function. These factors can impair respiratory mechanics and gas exchange [5,8,9]. Intra-operative factors such as type of anesthesia, sternotomy, cardiopulmonary bypass, and mechanical ventilation can also interfere with lung function by inducing a superficial breathing pattern at the expense of reduced lung volumes [10–13]. According to Elias et al. [6], postoperative pulmonary complications are related to reduced maximal respiratory pressures and expiratory peak flow rate (EPFR), as their values are lower than preoperative values at hospital discharge [14].

The ability of the respiratory system to eliminate secretion is related to the EPFR; very low values are associated with inability to cough and eliminate secretion with an inadequate cleaning of the tracheobronchial tree. Appropriate protection of the respiratory tract also depends on respiratory muscle strength [15,16].

Despite knowledge of the causes and mechanisms of lung function reduction after CABG surgery, the effect of preoperative clinical status on postoperative respiratory pressures and EPFR has not been clearly defined. The purpose of this study was to prospectively evaluate clinical and laboratory parameters that predict decreased respiratory function by CABG. We specifically assessed the influence of clinical and laboratorial variables on pre- and postoperative values of maximal respiratory pressures and EPFR of patients subjected to CABG surgery.

## MATERIAL AND METHODS

We prospectively evaluated 61 CAD patients who underwent CABG at Cardiovida Heart Hospital in Bauru and UNIMED Hospital in Bauru, Sao Paulo State, Brazil. The study was approved by the Sacred Heart University's Institutional Review Board. All patients read and signed the informed consent form.

One day before surgery, the following clinical information was obtained from patients and medical records: personal data, risk factors for CAD (arterial hypertension, diabetes

mellitus, dyslipidemia, smoking), number of coronary arteries with stenosis on angiography, and associated diseases. Heart failure and angina were classified according to New York Heart Association [17] and Cardiovascular Canadian Society [18] criteria, respectively. Venous blood was obtained after an overnight fast of at least 10 h for measurement of hematocrit and serum concentration of hemoglobin, urea, and creatinine. Maximal inspiratory (MIP) and maximal expiratory (MEP) pressures were measured using a manometer (*Instrumentation Industries, Inc.*). MIP was measured at maximal inspiration after a maximal expiration, and MEP was evaluated at maximal expiration after a maximal inspiration. Measurements were repeated until 3 values with a variation lower than 10% among them had been reached. If the last value was higher than the others, a new measurement was performed [19–22]. Patients rested 60 seconds after each measurement [23–27]. Expected normal values of maximum respiratory pressures were calculated according to age and sex using equations proposed by Neder et al. [27].

The measurement of EPFR was performed after a maximal inspiration, followed by a maximal and short forceful expiration using an asmaPLAN peak flow meter (*Vitalograph, Inc.*). The procedure was repeated until 3 values with a difference lower than 20 L/min among them had been obtained [28]. The EPFR values were compared to the expected normal values of Knudson's table [29] according to sex, age, and height.

All patients were subjected to CABG surgery through median sternotomy under cardiopulmonary bypass. Immediately after surgery, patients were transferred to intensive care units under endotracheal intubation with mediastinal drain and were mechanically ventilated with 100% FIO<sub>2</sub>, average tidal volume of 8 mL/kg, and 5–8 cm H<sub>2</sub>O of positive end-expiratory pressure. In this study, only patients under mechanical ventilation for a maximum period of 24 h were included. Surgery information including the number of bypass grafts and cardiopulmonary bypass and mechanical ventilation duration were recorded. On the first day after extubation, patients started physiotherapy sessions according to a protocol adapted by the hospital physiotherapist staff [30].

On the 5<sup>th</sup> postoperative day, MIP, MEP, EPFR, urea and creatinine serum concentration, and hemoglobin and hematocrit levels were analyzed.

## Data analysis

The general characteristics of patients are presented using descriptive statistics. Comparisons were performed using paired Student's *t* test and 2-way ANOVA. The association between variables was assessed by Pearson's correlation. Multiple logistic regression was performed to analyze the effect of preoperative factors on the respiratory parameters [31]. Statistical significance was accepted at the level of P<0.05.

## RESULTS

Sixty-one patients, 67.2% males and median age of 62.8±9.6 year-old were included in this study. There was no significant age difference between sexes (p=0.41). Arterial hypertension was found in 75.4% of the patients, diabetes in 31.2%, dyslipidemia in 63.9%, and chronic obstructive pulmonary disease

**Table 1.** Pulmonary parameters.

	Preoperative	Postoperative (5 <sup>th</sup> day)	Variation (%)
MIP (-)	70.2±25.2	50.6±19.5*	-26.9±14.7
MEP	81.7±24.8	62.3±20.4*	-22.7±13.5
EPFR	309±109	216±74.9*	-28.2±14.7

Data expressed as mean ± standard deviation. MIP – maximal inspiratory pressure (cm H<sub>2</sub>O); MEP – maximum expiratory pressure (cm H<sub>2</sub>O); EPFR – expiratory peak flow rate (l/min). \* p<0.001 vs. preoperative; Student's t test for dependent samples.

**Table 2.** Influence of clinical and laboratorial variables on maximal expiratory pressure evaluated in the pre-operative period.

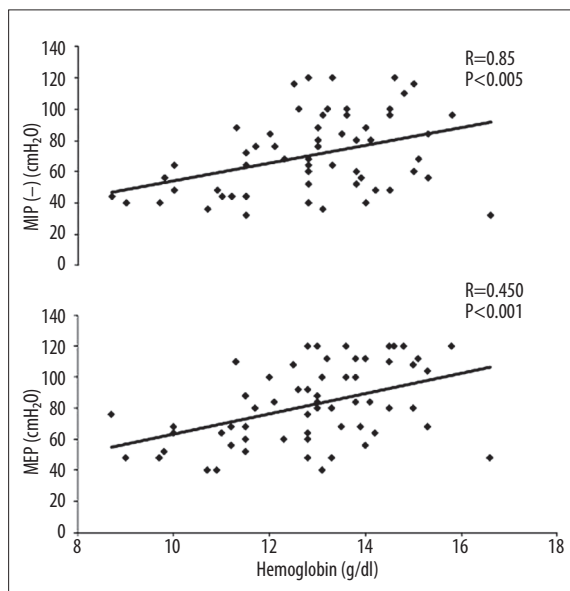
	Coefficient ±SE	Odds ratio
BMI	0.054±0.078	1.055
Angina	0.224±0.507	1.251
Smoking	-0.146±0.345	0.864
COPD	0.117±0.830	1.124
Hb	0.612±0.220	1.844*

SE – standard error; BMI – body mass index (kg/m<sup>2</sup>); COPD – chronic obstructive pulmonary disease; Hb – hemoglobin. Multiple logistic regression; \* p<0.05.

(COPD) in 16.4%. Fifteen patients (24.6%) were smokers, with 43±24 pack-years history, and 21 patients (34.4%) were ex-smokers, with an average smoking history of 36±29 pack-years. Forty-one (67.2%) had experienced a previous myocardial infarction and 11 (18.0%) had been subjected to coronary angioplasty. Heart failure functional class I was found in 4.92% of the patients, class II in 62.3%, and class III in 32.8%. Angina class I was observed in 8.20% of the patients, class II in 59.0%, and class III in 32.8%. Coronary angiography showed stenosis in 3 vessels in 63.9%, 2 vessels in 27.9% and 1 vessel in 8.2% of patients. Preoperative hemoglobin concentration was 12.8±1.71 g/dL.

Six patients (9.84%) received 2 bypass grafts, 23 (37.7%) received 3, 28 (45.9%) received 4, and 4 (6.56%) received 5 grafts. Five patients were concomitantly subjected to aortic valve replacement, 1 to ventricular aneurysmectomy, and 1 to atrial septal defect correction. All patients were subjected to cardiopulmonary bypass. The average time of cardiopulmonary bypass and mechanical ventilation were 102±25.7 minutes and 15.4±4.19 hours, respectively.

In the preoperative period, low values of MIP, MEP, and EPFR were found in 80.3%, 65.7%, and 88.5% of patients, respectively (Table 1). Maximal respiratory pressures and EPFR values were lower in females than in males (p<0.05). EPFR positively correlated with MIP and MEP values. Using the Neder et al. [27] equations for MIP and MEP normal values and the Knudson et al. [29] table for EPFR normal values, we classified our patients as presenting normal or decreased values for respiratory parameters. This classification was used in multiple logistic regression analysis. We observed that the higher the hemoglobin level, the greater the chance of presenting normal MEP values in the preoperative period (each increase of 1 hemoglobin unit increases

**Figure 1.** Pearson correlation between pre-operative hemoglobin levels and pre-operative maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP).

this chance by 1.84 times; Table 2). We did not observe any influence from clinical parameters on preoperative MIP, MEP, and EPFR values.

In the preoperative period, we observed a negative correlation between age and both MEP (p<0.05; r=-0.26) and EPFR (p<0.05, r=-0.27), and a positive correlation between hemoglobin levels and the respiratory parameters MIP, MEP (Figure 1), and EPFR.

**Table 3.** Variation in pulmonary parameters between pre- and postoperative periods according to class of angina and COPD.

	Angina class	COPD–	COPD+	p value
MIP (–)	II	–21.8±13.7	–24.5±12.1	<i>p</i> >0.05
	III	–27.4±11.7	–48.4±15.5	<i>p</i> <0.05
<i>p</i> value		<i>p</i> >0.05	<i>p</i> <0.01	
MEP	II	–21.0±13.6	–27.0±5.1	<i>p</i> >0.05
	III	–22.9±10.8	–35.3±23.1	<i>p</i> <0.05
<i>p</i> value		<i>p</i> >0.05	<i>p</i> >0.05	
EPFR	II	–26.9±14.5	–26.0±16.9	<i>p</i> >0.05
	III	–25.8±13.0	–34.1±14.6	<i>p</i> >0.05
<i>p</i> value		<i>p</i> >0.05	<i>p</i> >0.05	

Data expressed as mean ± standard deviation. MIP – maximal inspiratory pressure (cm H<sub>2</sub>O); MEP – maximum expiratory pressure (cm H<sub>2</sub>O); EPFR – expiratory peak flow rate (l/min); COPD – chronic obstructive pulmonary disease; two-way ANOVA.

In the 5<sup>th</sup> postoperative day, respiratory parameters were significantly reduced: MIP, MEP, and EPFR decreased by 26.9%, 22.7%, and 28.2%, respectively, compared to the preoperative values (Table 1). We found a positive correlation between MIP variation and both MEP and EPFR variation. We did not observe a correlation between cardiopulmonary bypass duration and the percentage of reduction in respiratory parameters.

The influence of angina severity and COPD on pulmonary changes between the preoperative period and the 5<sup>th</sup> postoperative day was assessed using 2-way ANOVA (Table 3). In patients with angina class II, the presence of COPD did not interfere on variations in MIP, MEP, and EPFR between pre- and postoperative periods. However, in patients with angina class III, the occurrence of COPD was associated with higher variations in MIP and MEP between these periods. When COPD was absent, angina severity did not influence the degree of pulmonary changes, while in COPD patients the presence of class III angina resulted in higher variation of MIP between pre- and postoperative periods.

Multiple logistic regression analysis showed that the clinical parameters, sex, age, smoking, heart failure, previous myocardial infarction or angioplasty, arterial hypertension, diabetes mellitus, and dyslipidemia were not associated with a reduction in postoperative respiratory parameters.

## DISCUSSION

In this study we evaluated the influence of preoperative clinical and laboratorial parameters on the pre- and postoperative values of maximal respiratory pressures and EPFR in patients subjected to CABG surgery.

Heart disease patients frequently present respiratory alterations in consequence of left ventricular dysfunction. Respiratory changes can be caused by lung congestion and/or blood flow reduction to respiratory muscles, which leads to a decrease of maximal respiratory pressures [6]. Respiratory muscle dysfunction in the preoperative period has been associated with a high incidence of pulmonary

complications in the postoperative period [32]. Therefore, as respiratory muscle dysfunction can be considered a morbidity and mortality risk factor in major surgeries involving the thoracic cavity, detecting this condition is helpful to risk stratification of patients undergoing heart surgery [33]. In our study, the MIP and MEP values in the preoperative period were lower than normal in 80.3% and 65.7% of patients, respectively. In accordance with the literature, maximal respiratory pressure findings of this study were lower in women than in men, and in aged patients [19,34].

We also evaluated EPFR, which is a respiratory muscle strength-dependent measure. Low EPFR has been associated with inability to cough and eliminate secretions, and consequently inadequate cleaning of the tracheobronchial tree [15,16]. In the preoperative period, 88.5% of our patients presented EPFR lower than the normal expected values, which is in accordance with the findings of other authors [14]. EPFR was positively correlated with MIP and MEP and negatively correlated with age.

Hemoglobin levels are related with physical capacity and muscle fatigue [35–37]. Reduction of hemoglobin level decreases the oxygen transport to skeletal muscles and may impair muscle force development [38]. We found a positive association between hemoglobin concentration and maximal respiratory pressures and EPFR values in the preoperative period, and observed that the increase of 1 hemoglobin unit increases the odds ratio in 1.84 to have normal MEP values. The mechanisms involved in pulmonary mechanics impairment related to anemia are not clear. Recently, Fernandes et al. [39] observed that in lung thoracic surgery, postoperative respiratory and infectious complications were related to the presence of anemia. This finding and our results reinforce the need to investigate and treat anemia before surgery if the procedure is not urgent.

We re-evaluated respiratory pressures on the 5<sup>th</sup> postoperative day, when patients had at least partially recovered from surgical pain and were close to discharge. Several authors have assessed postoperative pulmonary mechanics following cardiac surgery between the 4<sup>th</sup> and 6<sup>th</sup> postoperative



day [40–42]. In this study, respiratory pressures were lower than the preoperative values. Lung volume reduction in the postoperative period is caused by several factors, such as diaphragm dysfunction, chest pain, and lung and thoracic alterations [43,44]. Furthermore, any surgical procedure under general anesthesia is followed by some degree of respiratory dysfunction, even when the lungs are not directly involved [44].

Angina pectoris can cause muscle weakness, including the respiratory muscles, due to reduction of physical activity leading to muscle inactivity. Studies have shown that physical exercise programs and inspiratory muscle training improve physical capacity, diaphragm function, muscle strength, and dyspnea in patients with CAD [45]. COPD can also influence pulmonary mechanical function in both pre- and postoperative conditions. In this study, we evaluated the influence of both angina severity and COPD on pulmonary changes. We observed that severe angina (class III), in association with COPD, results in higher reductions in pulmonary pressures between the preoperative period and the 5<sup>th</sup> postoperative day. Analysis of multiple logistic regression failed to show a COPD effect on preoperative respiratory pressures and EPFR, probably due to the small number of COPD patients in our study.

EPFR values on the 5<sup>th</sup> postoperative day were significantly reduced compared to the preoperative period. A similar finding was reported by Giacomkazzi et al. [14] in patients subjected to heart surgery. Pain is an important factor responsible for reduction of respiratory muscle strength in the postoperative period. Muller et al. [46] showed that 51% of heart surgery patients still had sternotomy pain on the 7<sup>th</sup> postoperative day. In the postoperative period, routine procedures such as movement in bed and mediastinal drain manipulation can influence respiration mechanics and cough ability [47,48]. Another factor that contributes to impaired lung function and respiratory mechanics is the cardiopulmonary bypass (CPB) itself. Guizillini et al. [7] demonstrated that more severe lung dysfunction with reduction of volumes and lung capacities occur in surgeries with CPB. In our study we did not observe association between CPB duration and reduction of maximal respiratory pressures and EPFR. Although mechanical ventilation can induce deleterious effects on pulmonary function [49], we did not find an association between duration of mechanical ventilation and reduction of maximal respiratory pressures and EPFR postoperative values.

Postoperative pulmonary complications can also be associated with preoperative risk factors such as advanced age, previous lung diseases, smoking, poor nutritional status, impaired lung function and co-morbidities [5,50]. In our study, patient characteristics such as sex, age, smoking, heart failure, previous myocardial infarction or angioplasty, arterial hypertension, diabetes mellitus, and dyslipidemia were not associated with reduction of postoperative respiratory parameters.

Physical therapy has been shown to be important for heart surgeries results. In this study, patients showed (even on 5<sup>th</sup> postoperative day) values of maximal respiratory pressures and EPFR lower than those obtained in the preoperative period. Furthermore, postoperative complications can be

significantly reduced if lung dysfunction is recognized and appropriately managed in the preoperative period. Careful preoperative preparation including respiratory exercises in patients with chronic lung disease reduces postoperative complications significantly [51]. In our study, patients with associated severe angina and COPD presented higher postoperative reductions in maximal respiratory pressures than the others. These patients should receive more attention in the preoperative period with the indication of physical therapy. Implementation of physical therapy protocols in the pre- and postoperative periods is considered essential to prevent and treat pulmonary complications.

## CONCLUSIONS

In conclusion, older age and low hemoglobin levels are associated with preoperative low maximal respiratory pressures and expiratory peak flow rate. The combination of severe angina and COPD results in higher postoperative reduction of maximal respiratory pressures in CABG patients.

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