

ORIGINAL ARTICLE

Association of Respiratory Mechanics with Oxygenation and Duration of Mechanical Ventilation After Cardiac Surgery

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Abstract

Background: Mechanical ventilation (MV) and extracorporeal circulation (ECC) are associated with a decline in pulmonary mechanics that may affect gas exchange.

Objective: To evaluate the impact of pulmonary mechanics on MV duration and gas exchange in the postoperative period of cardiac surgery.

Methods: This was a cohort study in patients undergoing cardiac surgery. All patients underwent evaluation of pulmonary mechanics (static compliance and airway resistance) and arterial blood gas analysis upon admission to the intensive care unit (ICU) and were followed up until extubation and hospital discharge.

Results: The study included 50 patients (46 women, 52%) with a mean age of 57.5 ± 13.5 years. The MV duration was 7.7 ± 3.0 hours, static compliance was 35.5 ± 9.1 cm H₂O, resistance was 6.0 ± 2.3 cm H₂O, mean length of ICU stay was 2.9 ± 1.1 days, and oxygenation index was 228.0 ± 33.4 mmHg. No significant correlation was found between MV duration and static compliance ($p = 0.73$), but a strong correlation was found between static compliance and gas exchange ($r = 0.8$ and $p < 0.001$).

Conclusion: Pulmonary mechanics have a strong correlation with gas exchange and a weak correlation with MV duration after cardiac surgery. (International Journal of Cardiovascular Sciences. 2018;31(3):244-249)

Keywords: Respiration, Artificial; Oxygenation; Thoracic Surgery; Cardiac Surgical Procedures; Postoperative Care.

Introduction

Cardiac surgery is a form of treatment for coronary and myocardial pathologies aimed at increasing the patient's survival and quality of life. However, this type of surgery is associated with deleterious effects on the main body systems, such as the cardiovascular, central nervous, digestive, renal, and respiratory systems.¹ In this context, pulmonary complications emerge as an important cause of increased morbidity and mortality during the postoperative period.²

Patients undergoing cardiac surgery remain under mechanical ventilation (MV) in the immediate postoperative period until properly awoken and presenting good respiratory and hemodynamic stability.^{3,4} In some cases, the hospital stay may be even longer, and the patient may remain in the hospital for several days, often due to a requirement for vasoactive drugs.

Complications caused by cardiac surgery lead to multifactorial changes in pulmonary function, including alveolar collapse, decreased functional residual capacity, secretion retention, and decreased cough effectiveness.^{5,6}

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Physical therapy prescribed correctly during the preoperative and postoperative periods of cardiac surgery provides major benefits for patients with heart disease and may reduce substantially the occurrence of complications during these periods. With these potential benefits, the inclusion of physical therapists becomes fundamental in the hospital environment. However, there is scarce information in the literature regarding the impact of changes in respiratory mechanics on the duration of invasive MV (IMV) and whether this would increase the duration of stay in the intensive care unit (ICU).

Based on these considerations, this study aimed to evaluate the association between respiratory mechanics with oxygenation and duration of IMV and ICU hospitalization in patients in the postoperative period of cardiac surgery.

Methods

This was a prospective cohort study conducted with patients admitted to the *Instituto Nobre de Cardiologia / Santa Casa de Misericórdia* in the period between February and June 2016. The study was approved by the Research Ethics Committee at *Faculdade Nobre* (CAAE 51208115.1.0000.5654), and all patients signed an informed consent form in the preoperative period.

The inclusion criteria were individuals of both genders, aged 18 years or older, undergoing cardiac surgery (coronary-artery bypass grafting [CABG], aortic and/or mitral valve replacement, and correction of cardiac disease), who underwent sternotomy and extracorporeal circulation (ECC) under IMV in the immediate postoperative period. The exclusion criteria were: (a) hemodynamic instability requiring vasopressors at high concentration, (b) nonevaluable respiratory mechanics (for example, interaction with the MV), (c) progression to death during the ICU period, (d) sedation required for more than 48 hours, (e) absence of arterial catheter for collection of blood sample, and (f) refusal to participate in the research and to sign the informed consent form.

Patients who met the inclusion criteria were evaluated at the moment of admission to the ICU, soon after leaving the operating room. After receiving the initial support from the health care team, the physiotherapist on call evaluated the ventilatory mechanics and obtained from the ventilator (Vela, Viasys Healthcare, Critical Care Division, Palm Springs, CA, USA) the values related to peak and plateau pressure, static compliance of the respiratory system, and airway resistance.

During this evaluation, the patients remained in the supine position with the bed-head raised to a minimum of 30° while still under the effect of the surgical anesthesia, receiving ventilation at a controlled volume mode (6 mL/kg) with an inspiratory flow of 40 L/min, respiratory rate of 15 bpm, pause duration of 1 second, fraction of inspired oxygen (FiO₂) of 100%, and positive end-expiratory pressure (PEEP) of 5 cm H₂O. To calculate the static compliance, we used the formula tidal volume / (plateau pressure - PEEP) and to calculate resistance, the formula (peak pressure - plateau pressure) / flow.

Immediately after evaluating the ventilatory mechanics, the physician on call collected a sample of arterial blood through a catheter inserted into the radial artery. The sample was analyzed with a blood gas analyzer and the results related to arterial oxygen pressure (PaO₂) and FiO₂ were recorded. Levels of PaO₂ were divided by those of FiO₂, yielding the oxygenation index.

After these assessments, the patients continued to receive support according to the routine procedures of the unit, including the maintenance of strategies for weaning and decisions about the patient's discharge to the ward. The researchers refrained from interfering with the decisions and were limited to taking notes about the IMV duration (from ICU admission to extubation) and ICU stay.

Statistical analysis

The analysis was performed using SPSS 20.0, and the data are represented as mean and standard deviation. Normality was tested with the Kolmogorov-Smirnov test. Categorical variables were analyzed with the chi-square test and numerical variables (IMV duration, length of ICU stay, static compliance, resistance, and gas exchange) with Pearson's correction test. P values < 0.05 were considered statistically significant.

Results

Between February and June 2016, a total of 64 patients were hospitalized to undergo cardiac surgery. Of these, 14 were excluded from the study due to nonevaluable ventilatory mechanics (10 patients) or for refusing to sign the informed consent (4 patients). Therefore, we included 50 patients (52% women) with a mean age of 57.5 ± 13.5 years, who underwent cardiac surgery at *Instituto Nobre de Cardiologia / Santa Casa de Misericórdia em Feira de Santana*, Bahia (Brazil).

Table 1 presents the characteristics of the patients included in the study.

The mean static compliance was 35.5 ± 9.1 cm H₂O, the mean airway resistance was 6.0 ± 2.3 cm H₂O, and the mean duration of ICU stay was 2.9 ± 1.1 days.

No significant correlation was found between IMV duration with static compliance and resistance ($p = 0.73$ and $p = 0.51$, respectively) (Table 2).

Table 3 shows the static compliance and resistance as functions of the duration of hospitalization in the ICU, analyzed with the Spearman test. No statistically significant relationship was observed ($p = 0.83$ and $p = 0.98$, respectively).

On the other hand, a strong correlation was observed between static compliance and gas exchange (228.0 ± 33.4 , $r = 0.8$, $p < 0.001$) (Figure 1).

Discussion

The results of this study show that ventilatory mechanics (static compliance and resistance) had no influence on the IMV duration and length of ICU

Table 1 - Clinical, demographic, and surgical data of the patients who underwent cardiac surgery

Variables	Mean/SD	N (%)
Age (years)	57 ± 13	
Gender		
Male		24 (48)
Female		26 (52)
Type of surgery		
CABG		37 (74)
Valve replacement		12 (24)
Correction of congenital malformations		1 (2)
ECC duration (minutes)	72 ± 22	
MV duration (hours)	8 ± 3	
PaO ₂ /FiO ₂	228.0 ± 33.4	
Successful weaning		50 (100)

SD: standard deviation; N: number of patients; CABG: coronary-artery bypass grafting; MV: mechanical ventilation; ECC: extracorporeal circulation; PaO₂: arterial oxygen pressure; FiO₂: fraction of inspired oxygen.

Table 2 - Analysis of the ventilatory mechanics and duration of invasive mechanical ventilation (IMV) in patients undergoing cardiac surgery

Variable	
Static compliance (cm H ₂ O)	35.5 ± 9.1
IMV duration (hours)	8 ± 3
P ^a	0.73
Resistance (cm H ₂ O)	6.0 ± 2.3
IMV duration (hours)	8 ± 3
P [*]	0.51

Data are presented as mean ± standard deviation. *Pearson's test.

Table 3 - Analysis of the ventilatory mechanics and duration of hospitalization in the intensive care unit (ICU) in patients undergoing cardiac surgery

Variable	
Static compliance (cm H ₂ O)	35.5 ± 9.1
Duration of ICU stay (days)	2.9 ± 1.1
P [*]	0.83
Resistance (cm H ₂ O)	6.0 ± 2.3
Duration of ICU stay (days)	2.9 ± 1.1
P [*]	0.98

Data are presented as mean ± standard deviation. *Spearman test.

stay. However, static compliance presented a strong correlation with gas exchange in the postoperative period of cardiac surgery.

For Arcênio et al.,⁷ both anesthesia and certain surgeries predispose patients to changes in respiratory mechanics, pulmonary volumes, and gas exchange. Cardiac surgery, which is considered a large procedure, can trigger in the postoperative period respiratory changes related to several factors, including pulmonary and cardiac function in the preoperative period, use of ECC, and degree of sedation.

According to Badenes et al.,⁸ cardiac surgery associated with MV in the postoperative period causes significant structural and functional changes at a pulmonary level due to the inflammatory process that is also associated

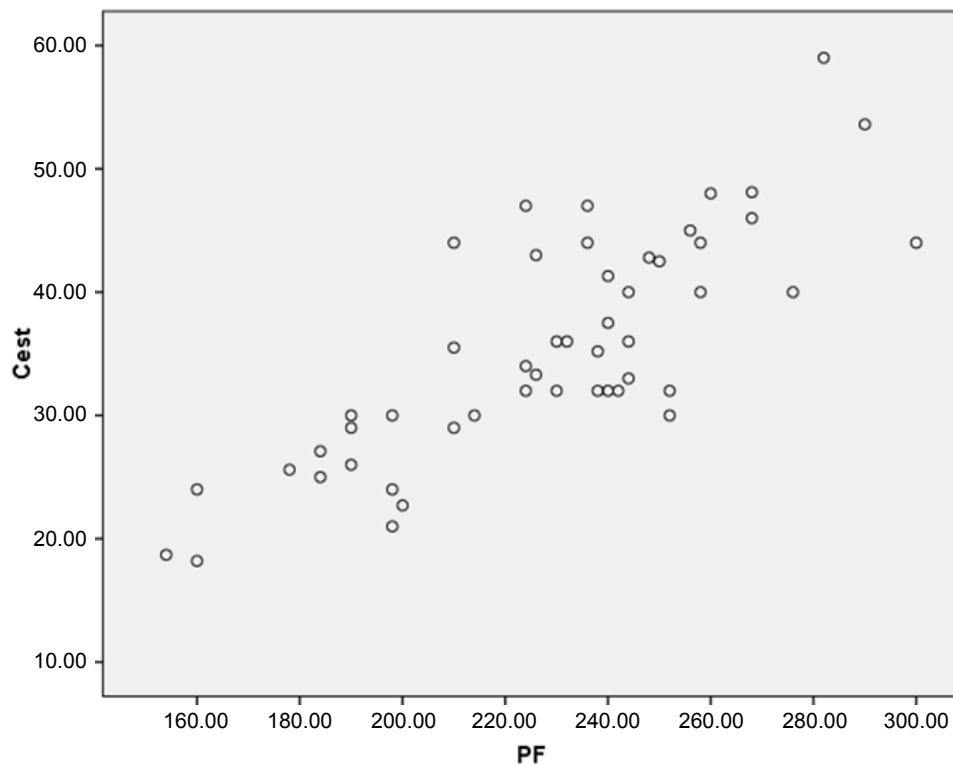


Figure 1 - Correlation between static compliance and gas exchange.

with the ECC, leading to reduced compliance of the respiratory system. In the present study, it was not possible to assess the parameters of pulmonary function prior to surgery.

Taking into consideration the pulmonary decline that occurs after cardiac surgery, Auler Jr et al.⁹ investigated the effect of PEEP on respiratory mechanics in patients submitted to cardiac revascularization. The authors applied different PEEP levels (0, 5, 10, and 15 cm H₂O) and demonstrated that with increases in positive pressure, there were decreases in airway resistance and elastance. It is worth mentioning that in the present study, all patients had the PEEP previously set at 5 cm H₂O and a low resistance was also observed with a mean of 6 cm H₂O.

Another factor that may increase the length of stay of the patient in the IMV and in the ICU is the intraoperative ECC duration. Canver & Chanda¹⁰ verified that ECC might be an independent factor for postoperative respiratory insufficiency, which consequently increases the duration of IMV and ICU stay. In an attempt to reduce the impact of ECC on the pulmonary function, Figueiredo et al.¹¹ evaluated 30 patients in the postoperative period

of CABG to verify the impact of continuous positive airway pressure (CPAP) on gas exchange during ECC and showed that there was no lasting improvement with the use of ECC at 10 cm H₂O.

The causes of unsuccessful weaning in patients undergoing cardiac surgery are mainly related to the presence of cardiac dysfunction and prolonged ECC duration. The ECC duration is one of the main factors to delay MV weaning after cardiac surgery, due to the important physiological disorder caused by the inflammatory response to the extracorporeal circuit.¹² In a study conducted by Nozawa et al.,¹² static pulmonary compliance was altered in patients undergoing cardiac surgery, showing values below the normal range, but this parameter was not sensitive enough to identify the prognosis of the patients in regards to MV weaning. Airway resistance was increased in all patients; however, no significant difference was observed between the patients who progressed to MV independence and those who evolved to weaning failure.

In relation to gas exchange, the present study found that the lower the static compliance, the lower the

oxygenation index. Rodrigues et al.¹³ assessed 942 patients in order to verify the factors associated with dysfunctional exchanges after cardiac surgery and observed that the presence of pneumonia, cardiac arrhythmia, and hemotherapy correlated with such dysfunction. Other authors have demonstrated that the body mass index and smoking may be associated with hypoxemia, which in turn is associated with a decline in pulmonary compliance.^{14,15}

As an alternative to correct this decline in pulmonary compliance, Lima et al.¹⁶ investigated the impact of different levels of PEEP on gas exchange in patients undergoing CABG. The authors evaluated 78 individuals divided into three groups according to PEEP level (5, 8, and 10 cm H₂O) and observed that changes in PEEP level do not interfere in the exchanges. When the authors analyzed the group that received a PEEP of 5 cm H₂O (an identical level to that used in the present study), they observed a mean value of 320.5 ± 65.0 mmHg, whereas in the current study, the mean value was 228.0 ± 33.4 mmHg.

The limitations of the present study include the lack of information regarding the comorbidities presented by the patients included in the analysis. Another limitation was the lack of information about static compliance, resistance, and gas exchange in the preoperative period.

Conclusion

Based on the findings of this study, we conclude that pulmonary mechanics correlate strongly with gas exchanges and weakly with the duration of MV in the postoperative period of cardiac surgery.

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Author contributions

Conception and design of the research: Oliveira LFL, Queiroz TC, Santana VLL, Cordeiro ALL. Acquisition of data: Oliveira LFL, Queiroz TC, Santana VLL. Analysis and interpretation of the data: Cordeiro ALL, Melo TA. Statistical analysis: Cordeiro ALL, Melo TA. Writing of the manuscript: Oliveira LFL, Queiroz TC, Santana VLL, Cordeiro ALL. Critical revision of the manuscript for intellectual content: Melo TA, Guimarães AR, Martinez BP.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Faculdade Nobre under the protocol number 1.405.817. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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