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ORIGINAL ARTICLE

Expiratory positive airway pressure on oxygenation and hemodynamics in patients submitted to coronary artery bypass grafting

Pressão positiva expiratória das vias aéreas sobre a oxigenação e hemodinâmica em pacientes submetidos a revascularização do miocárdio

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Abstract

Introduction: Expiratory Positive Airway Pressure (EPAP) is the application of an expiratory resistance to maintain positive airway pressure and has been widely used to prevent possible complications in the postoperative period of cardiac surgery. *Objective*: To describe the behavior of oxygenation and hemodynamics during the use of EPAP in patients undergoing coronary artery bypass grafting (CABG). *Methods*: This was a cross-sectional study that evaluated peripheral oxygen saturation (SpO_2), heart rate (HR), respiratory rate (RR), systolic (SBP), diastolic (DBP) and mean (MAP) blood pressure, arterial oxygen pressure (PaO_2), arterial carbon dioxide pressure ($PaCO_2$) and oxygenation index that was calculated by dividing PaO_2 by inspired oxygen fraction

(FiO_2), patients were evaluated at rest and in the first postoperative day. The EPAP was performed with the patient in the armchair sedation, and an arterial blood gas analysis was collected and analyzed to verify the PaO_2, $PaCO_2$, SaO_2 and PaO_2/FiO_2 values. The mask on the patient's face was verbally stimulated to breathe normally while applying an expiratory resistance of 12 cmH_2O for ten minutes. Immediately after the application of EPAP, the patients had new blood gas analysis performed and the hemodynamics analyzed. *Results*: We evaluated 58 patients for research, 41 (71%) male and with a mean age of 54 ± 8 years. The use of EPAP in the postoperative period led to improvement of all blood gas variables except $PaCO_2$. There was an improvement in SaO_2 (%) pre-EPAP 94 ± 3 and post-EPAP 98 ± 2, PaO_2/FiO_2 pre-EPAP 279 ± 10 and post-EPAP 346 ± 8, PaO_2 (mmHg) pre-EPAP 78 ± 8 and post-EPAP 97 ± 7. *Conclusion*: We concluded that the application of EPAP had a positive impact on oxygenation in patients undergoing CABG without generating adverse effects on hemodynamics.
Keywords: myocardial revascularization; respiratory function tests; intrinsic positive-pressure respiration.

Resumo

Introdução: A pressão positiva expiratória nas vias aéreas (EPAP) é a aplicação de uma resistência expiratória para manter a pressão positiva nas vias aéreas e também tem sido amplamente utilizada para prevenir possíveis complicações no pós-operatório de cirurgia cardíaca. *Objetivo*: Descrever o comportamento da oxigenação e hemodinâmica durante o uso de EPAP em pacientes submetidos à cirurgia de revascularização do miocárdio (RM). *Métodos*: Estudo transversal que avaliou saturação periférica de oxigênio (SpO_2), frequência cardíaca (FC), frequência respiratória (FR), pressão arterial sistólica (PAS), diastólica (PAD) e média (PAM), pressão arterial de oxigênio (PaO_2), pressão arterial de dióxido de carbono ($PaCO_2$) e índice de oxigenação calculado dividindo a PaO_2 pela fração inspirada de oxigênio (FiO_2), os pacientes foram avaliados em repouso, no primeiro dia de pós-operatório. A EPAP foi realizada com o paciente em sedestação na poltrona e uma gasometria arterial foi coletada e analisada para verificar os valores de PaO_2, $PaCO_2$, SaO_2 e PaO_2/FiO_2. Foi aplicada uma resistência expiratória de 12 cmH_2O por dez minutos. Imediatamente após a aplicação do EPAP, os pacientes tiveram nova análise gasométrica e a hemodinâmica analisada. *Resultados*: 58 pacientes, 41 (71%) do sexo masculino e com idade média de 54 ± 8 anos foram avaliados. O uso de EPAP no pós-operatório levou à melhora de todas as variáveis gasométricas, exceto $PaCO_2$. Houve uma melhora na SaO_2 (%) pré-EPAP 94 ± 3 e pós-EPAP 98 ± 2, PaO_2/FiO_2 pré-EPAP 279 ± 10 e pós-EPAP 346 ± 8, PaO_2 (mmHg) pré-EPAP 78 ± 8 e pós-EPAP 97 ± 7. *Conclusão*: Concluiu-se que a aplicação do EPAP teve um impacto positivo na oxigenação em pacientes submetidos à RM sem gerar efeitos adversos na hemodinâmica.

Palavras-chave: revascularização do miocárdio; testes de função respiratória; respiração por pressão positiva intrínseca.

Introduction

Cardiovascular diseases represent a serious public health problem in developing countries, being characterized as an epidemic due to the rapid growth of morbidity and mortality resulting from its occurrence [1]. Deaths from cardiovascular diseases in Brazil represent 32.6% of deaths, reaching 20 million in 2030 and deaths per year from cardiovascular diseases [2].

Some conditions such as population aging, obesity, smoking, physical inactivity and systemic arterial hypertension are important factors that predispose to the increased incidence of these diseases [3]. One of the alternatives to alleviate the symptoms of these diseases is cardiac surgery (CC), which aims to increase survival and improve quality of life [4].

Factors such as anesthesia, cardiopulmonary bypass (CPB), and postoperative drainage may lead to a decline in pulmonary function that causes physiological changes that affect oxygenation [4]. Respiratory physical therapy is essential to this patient profile using techniques and exercises that help reverse this condition. Depending on the type of patient and surgery, breathing patterns, incentive spirometry and positive end-expiratory pressure (PEEP) can be used or associated with other types of exercises for patient optimization [5].

PEEP is the application of resistance in the expiratory phase in order to maintain positive airway pressure. It is used in both mechanical ventilation and spontaneous breathing patients. Pulmonary expansion technique with the use of positive pressure impacts the improvement of gas exchange, optimizing oxygenation and reducing the arterial lactate level of postoperative cardiac surgery patients [6].

Positive Expiratory Airway Pressure (EPAP) has been widely used in the prevention of some possible postoperative complications of cardiac surgery with the objective of recruiting alveoli, improving oxygen exchange and thus reducing respiratory distress. However, its application can impact the hemodynamics of these patients [7].

Therefore, the aim of this study was to describe the behavior of oxygenation and hemodynamics during the use of EPAP in patients undergoing myocardial revascularization.

Methods

This is a cross-sectional study. It was carried out at a cardiology referral hospital in the city of Feira de Santana, Bahia, from September 2017 to November 2018. The study was approved by the Ethics Committee of the Noble Faculty of Feira de Santana, under the opinion number 2,002,971. All participants signed an Informed Consent Form.

Inclusion criteria were individuals of both sexes, aged 18 years and over and submitted to myocardial revascularization via median sternotomy and cardiopulmonary bypass. As an exclusion factor: intubated patients with severe pulmonary disease, hemodynamically unstable (mean blood pressure < 70 mmHg and > 100 mmHg, systolic blood pressure < 100 mmHg, fracture or surgery on the face that prevented mask placement, claustrophobia, arrhythmias, medical contraindication for the procedure and individuals who did not cooperate or did not understand the proposed technique.

Patients were evaluated at rest and at the time of intervention on the first postoperative day. With the patient in armchair sedation, preferably before the diet, an arterial blood gas analysis was collected and analyzed to verify the PaO_2, $PaCO_2$, SaO_2 and PaO_2/FiO_2 values, and all patients wore a 28% venturi mask. In addition, they were monitored for evaluation of hemodynamic variables. At this time, the mask was placed on the patient's face, which were verbally stimulated to breathe normally while applying an expiratory resistance of 12 cmH_2O for ten minutes. Immediately after the application of EPAP, the patients had new blood gas analysis and the hemodynamics analyzed.

Before, during and after the procedure, patients who presented signs of respiratory distress, SpO_2 decrease (< 90%), RR elevation (> 30 bpm), HR elevation (> 130 bpm), MAP alteration (< 70 or > 100 mmHg) and / or agitation were excluded from the study.

For data analysis, the *SPSS 20.0 software* was used. Normality was assessed using the Shapiro-Wilk test. Numerical variables were expressed as mean and standard deviation or median and interquartile range. For comparison of blood gas and hemodynamic values before and after EPAP application was performed using the paired Student's t test. It was considered significant when $p < 0.05$.

Results

During the research period, 70 patients were admitted for cardiac surgery, 8 of whom were excluded because three did not understand the therapy and 4 had a medical contraindication. 58 patients were included in the study, 41 (71%) male and mean age 54 ± 8 years. The other clinical and surgical data in table I.

The application of EPAP in the postoperative period resulted in improvement of all blood gas variables except $PaCO_2$ (Table II).

The application of positive pressure caused a change in hemodynamic variables, but without statistical significance and not related to adverse events. The values are shown in table III.

Table I - *Clinical and surgical data of the studied patients*

Variable	
Sex	
Male	41 (71%)
Female	17 (29%)
Age (years)	54 ± 8
BMI (kg/m²)	27 ± 6
Comorbidities	
SAH	36 (62%)
DM	26 (45%)
DLP	22 (38%)
CPB time (min)	87 ± 9
MV time (hours)	6 ± 3

BMI = Body Mass Index; MR = Myocardial Revascularization; TV = Valve Exchange; SAH = Systemic Arterial Hypertension; DM = Diabetes Mellitus; DLP = dyslipidemia; CPB = Extracorporeal Circulation; VM = Mechanical Ventilation

Table II - *Behavior of oxygenation variables in patients undergoing EPAP*

Variable	Pré-EPAP	Pós-EPAP	p[a]
PaO_2 (mmHg)	78 ± 8	97 ± 7	< 0,01
$PaCO_2$ (mmHg)	37 ± 5	38 ± 7	0,86
PaO2/FiO_2	279 ± 10	346 ± 8	< 0,01
SaO_2 (%)	94 (91-97)	98 (96–99)	0,04

A = Paired Student's t-test; PaO_2 - Arterial Oxygen Pressure; $PaCO_2$ - Carbon Dioxide Blood Pressure; SaO_2 - Arterial Oxygen Saturation

Table III - *Hemodynamic behavior of patients submitted to EPAP application*

Variable	Before-EPAP	After-EPAP	p[a]
HR (bpm)	89 ± 11	94 ± 7	0,34
SBP (mmHg)	112 ± 21	103 ± 24	0,14
DBP (mmHg)	78 ± 14	71 ± 16	0,65
MAP (mmHg)	87 ± 15	81 ± 11	0,23
RR (ipm)	16 ± 3	18 ± 2	0,31

A = Paired Student's t-test; HR - Heart Rate; SBP = systolic blood pressure; DBP = Diastolic Blood Pressure; MAP = Mean Arterial Pressure; bpm = beats per minute; mmHg = millimeters of mercury

Discussion

In the present study, it was observed that the effects of Expiratory Positive Pressure (EPAP) on the airways on oxygenation in patients undergoing cardiac surgery improved all postoperative oxygenation variables, including partial oxygen pressure (PaO_2) and oxygen saturation (SaO_2), but without impact on hemodynamics.

Haeffner *et al.* [8], who evaluated the use of ventilatory-associated EPAP in patients undergoing myocardial revascularization surgery, reported that by analyzing the pulmonary variables studied, there was a significant improvement in pulmonary function within 30 days in the group using the EPAP mask, when compared to baseline values, whereas in the control group there was no restoration of pulmonary function after surgery. In general, the use of EPAP promotes, at the physiological level, improvement of gas exchange due to the recruitment of collapsed alveoli, leading to increased pulmonary expansion, so its application in bedridden patients accelerates the restructuring of pulmonary function, decreasing the time in hospital beds as well as the repercussions related to this state.

The period of effects of EPAP therapy on the variables oxygen saturation, respiratory rate and heart rate was analyzed in nine patients with acute myocardial infarction within 72 hours. In this study, with PEEP up to 10 cmH_2O, the heart and respiratory rates before and after the use of EPAP both showed no clinical difference, but promoted increased oxygen saturation levels [9].

According to Cordeiro *et al.* [7] the use of 12 cmH_2O pressure increased PaO_2 without significance, and such significance was only achieved when the authors used a PEEP of 15 cmH_2O. In our study, the 12 cmH_2O PEEP was sufficient to significantly increase this value, this difference may be due to the fact that in the study this PEEP was used in noninvasive ventilation.

During CPAP application in patients, after cardiac surgery in the ward, evidenced that PaO_2 showed a reduction when compared only with oxygen utilization [10]. The difference may have been due to the type of environment, as the first study was performed in the ward and ours in the ICU. Another difference may have been due to the excessive use of oxygen used by the oxygen therapy group [10].

Lima *et al.* [11] found no gas changes in myocardial revascularization surgeries, but significant changes were observed in the present study. This difference may or may not be related to the load imposed on the PEEP, in the study by Lima *et al.* [11] the PEEP was 10 cmH_2O, in which 12 cmH_2O was used. The use of PEEP makes sense primarily because it recruits unstable alveoli and improves gas exchange, but in a large clinical study using high PEEP (12 cmH_2O) and recruitment maneuvers during open abdominal surgery, no protection against postoperative pulmonary complications was found operative [12].

Correlating similar studies, it was evidenced by Setak-Berenjestanaki [13] research that the use of 10 cmH_2O PEEP in patients with mechanical ventilation in the ICU after CC can lead to a significant reduction in the risk rate with incidence of atelectasis taking into account alveolar recruitment and redistribution of extravascular fluid. Already in a second similar study [14] on the effect of positive pressure, it shows that the PEEP of 8 cmH_2O and 5 cmH_2O had no significant effect on reducing this incidence. In the related research for improvement in all oxygenation variables, using PEEP of 12 cmH_2O, it is suggestive of a lower risk rate in atelectatic conditions.

In postoperative cardiac surgery patients, it was found that the application of a 10 cmH_2O EPAP was associated with a small increase in mean and pulmonary arterial pressures, pulmonary artery occlusion pressure and central venous pressure [15]. In our study there was an increase in heart rate, while SBP, DBP and MAP decreased, but without significance even with the use of higher pressures. Possibly, between studies, variations may be related to the use of vasoactive drugs, although during the intervention there was no increase in drugs, but the flow they were using may have contributed to the maintenance of hemodynamic variables.

In another study, 10 cmH_2O PEEP was used in postoperative cardiac surgery patients, in their results there was a decrease in cardiac output, increased central venous pressure and systolic volume variation, but had little effect on blood pressure mean and HR. In our study, we also observed a slight decrease in hemodynamic parameters with higher PEEP. Theoretically, this decrease in CD may have been due to the effect of decreased venous return and decreased right ventricular preload that may limit hemodynamic elevations [16].

Thofehrn *et al.* [17] applied, in patients with congestive insufficiency, the six-minute walk test and 20 cmH2O EPAP, generating changes in hemodynamic variables. In our study, a lower pressure was used, which caused a change in the variables. This result may have been generated due to the pressure level that was not so high, that is, the higher the applied pressure level, the greater the volume of the alveolus reached and the subsequent increase in transpulmonary pressure and interalveolar pressure at the end of expiration [18,19].

In our study, we used 12 cmH_2O PEEP and no statistical significance was observed in hemodynamic parameters. These effects generated by the application of EPAP, regardless of the blood pressure level, can be explained by increased intrathoracic pressure, compression of the superior and inferior vena cava, decreased atrial and ventricular filling and, consequently, reduced cardiac output [20].

It was analyzed in our study that the use of PEEP in patients in the postoperative period of CHD is a safe and well-tolerated technique, since it did not cause any adverse events or hemodynamic repercussions. The effects caused by PEEP are integrated responses in the central nervous system, triggering the activation of the sympathetic and parasympathetic systems, which modulate the cardiovascular system, especially BP and HR [21,22].

Conclusion

We concluded that the application of EPAP had a positive impact on oxygenation in patients undergoing myocardial revascularization without adverse effects on hemodynamics.

Potencial conflict of interest
No potential conflicts of interest relevant to this article have been reported.

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Authors´contribution
Conception and research design: Cordeiro ALB, Andrade JB, Santos LT, Silva ATA, Pedreira AES; *Data collection*: Cordeiro ALB, Andrade JB, Santos LT, Silva ATA, Pedreira AES; *Data analysis and interpretation*: Cordeiro ALB; *Writing of the manuscript:* Cordeiro ALB, Andrade JB, Santos LT, Silva ATA, Pedreira AES; *Critical review of the manuscript for important intellectual content*: Cordeiro ALB, Guimarães ARF, Ferreira GVD, Soares LO

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