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Assessment of noninvasive ventilation with two levels of positive airway pressure in patients after cardiac surgery

Avaliação da ventilação não-invasiva com dois níveis de pressão positiva nas vias aéreas após cirurgia cardíaca

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Abstract

Introduction: **The application of two levels of ventilation by positive pressure (BiPAP®) associated with conventional respiratory therapy (CRT) in postoperative periord of cardiac surgery may contribute to reduction of pulmonary complications.**

Objectives: **To evaluate the safety and compliance of preventive application of BiPAP® CRT associated with immediate postoperative myocardial revascularization.**

Methods: **26 patients undergoing coronary artery bypass grafting were randomly allocated in one of the groups. Patients of the Control Group (CG) were treated only with conventional respiratory therapy, compared to BiPAP group (BG) (in addition to conventional respiratory therapy the patients were subjected to 30 minutes of ventilation by two levels twice a day). The conventional respiratory therapy was held in both groups, twice a day. All patients were evaluated for vital capacity, airway permeability, maximal respiratory pressures, oxygen saturation, heart rate, respiratory frequency, Volume Minute, tidal volume, systolic and diastolic blood pressure. Evaluations were performed during hospitalization preoperatively, immediately after extubation, 24h and 48h after extubation.**

Results: **In CG 61.5% of patients had some degree of atelectasias, in comparison to 54% of BG (*P*=0.691). The vital capacity was higher in the GB postoperatively (*P*<0.015). All the other ventilometric, gasometric, hemodynamic and manometric parameters were similar between groups.**

Conclusion: **Coronary artery bypass grafting leads to deterioration of respiratory function postoperatively, and the application of positive pressure ventilation (BiPAP®) may be beneficial to restore lung function more quickly, especially vital capacity, safely, and well accepted by patients due to greater comfort with the sensation of pain during the execution of respiratory therapy.**

Descriptors: **Cardiovascular surgical procedures. Physical therapy modalities. Postoperative care. Pulmonary ventilation.**

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Resumo

Introdução: **A aplicação de ventilação por dois níveis de pressão positiva (BiPAP®) associada à fisioterapia respiratória convencional (FRC) no pós-operatório (PO) imediato de cirurgia cardíaca pode contribuir para a diminuição das complicações pulmonares.**

Objetivo: **Avaliar a segurança e a adesão da aplicação preventiva do BiPAP® associado a FRC no PO imediato de revascularização do miocárdio.**

Métodos: **Vinte e seis pacientes submetidos a revascularização do miocárdio foram aleatoriamente alocados. O Grupo Controle (GC) foi tratado com FRC, o Grupo BiPAP (GB) foi submetido a 30 minutos de BiPAP®, duas vezes ao dia, associado à FRC. A FRC foi realizada em ambos os grupos, duas vezes ao dia. Todos os pacientes foram avaliados quanto: capacidade vital, permeabilidade das vias aéreas, pressões respiratórias máximas, saturação de oxigênio, frequência cardíaca, frequência respiratória, volume minuto, volume corrente, pressões arteriais sistólica e diastólica. As avaliações foram realizadas durante a internação no pré-operatório, imediatamente após a extubação, e na 24ª e 48ª horas após extubação.**

Resultados: **No GC, 61,5% dos pacientes tiveram algum grau de atelectasias, no GB, 54% (*P*=0,691). A capacidade vital foi estatisticamente maior no GB no PO (*P*<0,015). Todos os outros parâmetros de ventilometria, gasometria, manovacuometria e hemodinâmicos foram semelhantes entre os grupos.**

Conclusão: **A cirurgia de revascularização do miocárdio leva à degradação da função respiratória no PO, e a aplicação da ventilação com pressão positiva (BiPAP®) pode ser benéfica para reestabelecer a função pulmonar mais rapidamente, principalmente a capacidade vital, de forma segura, sendo bem aceita pelos paciente, devido ao maior conforto em relação à sensação de dor durante a execução da fisioterapia respiratória.**

Descritores: **Procedimentos cirúrgicos cardiovasculares. Modalidades de fisioterapia. Cuidados pós-operatórios. Ventilação pulmonar.**

INTRODUCTION

The frequency of surgical procedures has increased steadily in recent decades [1]. Despite the modernization of the procedures used in cardiac surgery, pulmonary function is still affected and postoperative pulmonary complications are still a significant cause of mortality and morbidity in the postoperative period [1-6].

Patients undergoing cardiac surgery, most of the time, influenced by pre-, peri- and post-operative (PO) factors, are predisposed to pulmonary complications that become more evident in the postoperative period. In the preoperative period, the factors that contribute to changes in pulmonary function are mainly pulmonary disease, smoking, obesity and lung congestion from heart failure [7].

During the postoperative period, patients may experience changes in lung volume and capacity, due to several factors, including a restrictive phenomenon of change in thoracic dynamics caused by chest pain generated by drains and surgical incisions of the type median sternotomy, thereby undermining the ventilatory dynamics. Another factor interfering with lung function includes positioning for surgery and cardiopulmonary bypass (CPB) itself, leading to a significant inflammatory reaction. Also anesthesia, as well as its time of use, lead to a change in the breathing pattern, which becomes superficial, which added to the diaphragmatic dysfunction culminate in alveolar hypoventilation, reduction in airway responsiveness and hypoxemia [8].

The abnormalities in pulmonary mechanics after cardiac surgery are characterized by a restrictive pattern with decreased vital capacity (VC) and functional residual capacity (FRC) [9.10]. The VC is usually reduced to about 40% to 50% of preoperative values during a period of at least 10 to 14 days [11-14]. The FRC is reduced to about 70% of preoperative levels returning to normal within 7 to 10 days [15].

This pattern of restrictive lung disease and hypoxemia prevalent in cardiac surgery PO cannot be prevented, but can be modified. Therefore, the basis of therapeutic modalities used is the maintenance or restoration of Functional Residual Capacity (FRC) [7].

The mechanical and physiological changes add up, compromising lung function and decreasing respiratory muscle strength (RMS) in order to delay the recovery of the patient in the postoperative cardiac surgery, for the

proper maintenance of RMS is essential for ventilation and facilitation of airway clearance [15].

Atelectasis and pneumonia, caused by changes in respiratory mechanics, are the main pulmonary complications resulting from heart surgery, and these can cause increased breathing effort and decreased lung capacity, thus, increasing predisposition to lung infections [10].

The incidence of atelectasis in patients undergoing cardiac surgery with CPB is high, ranging from 60% to 90% [16].

Pneumonia can be attributed to the decrease in expiratory flow and ciliary rate and the inhibition or ineffective cough [10].

Physical therapy in the postoperative period after the arrival of the patient in the intensive care unit contributes much to the appropriate ventilation and successful extubation [17].

Respiratory therapy is often used in the prevention and treatment of postoperative complications such as retention of secretions, atelectasis and pneumonia [18].

In recent years, scientific studies have investigated therapeutic strategies that could prevent or minimize pulmonary complications after cardiac surgery [19,20].

For treatment and prevention of respiratory complications that usually occur in the postoperative period of cardiac surgery many different therapies have been applied such as: Conventional Respiratory Physiotherapy (CRF), Incentive Spirometry, Positive Pressure in a non-invasive mask with *Positive end-expiratory pressure* (PEEP), continuous positive airway pressure (CPAP) and ventilation with two levels of Positive Airway Pressure (BiPAP ®), leading to significant decrease in the incidence of these complications compared to patients who did not undergo any physical therapy approach [21 -23].

The non-invasive ventilation (NIV) reduces the work of breathing and increased respiratory system compliance by reversing lung microatelectasis [24], and it is independent of patient effort to generate deep breaths, and thus an advantage over other methods, especially in the immediate postoperative period in which the patient is uncooperative or unable to perform maximal inspiration, promoting an increase of both volume and lung capacity [25]. It is also found that the use of NIV for at least two days after surgery, leads to beneficial effects on pulmonary function and oxygenation indices [7]. There are also the hemodynamic benefits such as reduced preload by reducing venous return, decreased afterload of the left ventricle by reducing its transmural pressure and increased cardiac output, which leads to improved performance of the heart as a pump [26].

Several authors have shown that the use of NIV may be useful in improving lung function and gas exchange in the postoperative period of CABG surgery, however the clinical significance of these findings need confirmation [27,28].

Given the number of complications that occur in the postoperative cardiac surgery and the beneficial effects of NIV by applying two pressure levels, found in the literature, this study is appropriate, contributing to greater number of scientific works substantiating this technique of ventilation.

The objective of this study is to evaluate the safety and adherence, and effectiveness of application of noninvasive ventilation for two levels of positive pressure associated with CRF, on the early postoperative period of patients undergoing coronary artery bypass grafting.

METHODS

We evaluated 26 patients undergoing elective cardiac surgery for CABG with CPB and median incision performed at the Hospital of the School of Medicine of Ribeirão Preto - USP. All patients signed an informed consent by providing guidance on the proposed protocol, in compliance with Resolution 196/96 of the CNS, and this study was approved by the Ethics Committee of Hospital das Clínicas de Ribeirao Preto. We excluded those who underwent emergency surgery, low level of understanding and age less than 40 years and surgeries performed without the use of CPB.

The protocol was extended by two days after surgery. Patients were randomly selected and gathered into two groups, forming a BiPAP Group (BG), with 13 patients treated with CRF associated with BiPAP ® applications (twice a day, lasting 30 minutes each application), and Control Group (CG) with 13 patients treated with CRF.

Evaluations were performed preoperatively, immediately after extubation (IPE), 24 and 48 hours after extubation. Preoperatively, patients received information about surgical procedures and physical therapy to be performed in different periods of recovery (hospitalization period), all being subject to an assessment clinic, which contained personal data, demographics, medical diagnosis, personal history data related to surgery, and specific measures such as RMS, Spirometry and peak expiratory flow.

RMS was obtained with a manometer Ger-Air brand, scaled in cmH_2O, according to the methodology proposed by Black and Hyatt [29]. For the maneuver, the patient was instructed to perform a maximal inspiratory effort after full exhalation to measure maximal inspiratory pressure (MIP). Likewise, the patient was instructed to perform a maximal expiratory effort at the end of a maximal inspiration, to measure maximal expiratory pressure (MEP).

Spirometry was used to obtain tidal volume (TV), minute volume (MV) and vital capacity (VC), through the use of a brand of portable digital spirometer Electronic spirometer. All measurements (TV, MV and VC) were evaluated with the patient breathing spontaneously, sitting position,

wearing a nose clip. To obtain the MV, the patient was asked to inhale and exhale slowly for a minute, where it was recorded the value of MV and respiratory rate (RR). The VC was obtained by dividing the MV by RR. To obtain the VC, the patient was asked to inhale deeply as much as I could and then drop all the air until the lungs completely empty. The maneuvers were performed three times. RMS was measured by the movements of the chest during the respiratory cycles performed in one minute.

After performing heart surgery, patients received the treatment proposed in accordance with your group, and the CRF consisted of diaphragmatic breathing exercises associated with active movement and / or active-assisted on upper limbs, lower limb mobilization, clearance maneuvers, relief of cough and reexpansion techniques. The application of BiPAP ® was used in the spontaneous mode, cycled at two levels of positive pressure with a pressure level during inspiration (IPAP) 8 to 12 cmH_2O and a pressure level during exhalation (EPAP) of 6 cmH_2O.

RESULTS

Table 1 shows the anthropometric characteristics, demographic, clinical and surgical patients involved in this study for CG and BG. Figure 1 illustrates the behavior of the values of respirometry. Both the MV, such as TV and VC showed significant decreases when compared to those of postoperative to preoperative, all with $P < 0.001$. However, only the VC values between groups were significant ($P = 0.015$).

With regard to the FP, Figure 2 shows the results obtained from the pre-operative until the 48th hour after extubation, and we observed that in both groups, the significant drop when comparing the values obtained in the postoperative the pre-operative with $P < 0.001$. However, there was no significant difference in values between the groups ($P = 0.327$).

Table 1. Anthropometric, clinical and surgical characteristics in mean and standard deviation of the patients studied.

Variables	Control Group N = 13	BiPAP Group N = 13	*P*
Gender (n, %)			
Male	7 (53.8%)	10 (76.9%)	0.411
Female	6 (46.2%)	3 (23.1%)	
Weight (kg)	74.14 ± 14.90	68.52 ± 11.64	0.488
Height (m)	1.63 ± 0.06	1.64 ± 0.13	0.572
BMI (kg/m²)	27.96 ± 5.57	25.56 ± 2.55	0.448
Time of surgery (min)	238.5 ± 33.69	253.1 ± 54.07	0.503
Time of Ao clamping (min)	50.2 ± 21.4	56.6 ± 19.8	0.064
Time of CPB (min)	68.9 ± 22.7	76.3 ± 27.1	0.152

Unpaired Student's t test / Mann-Whitney

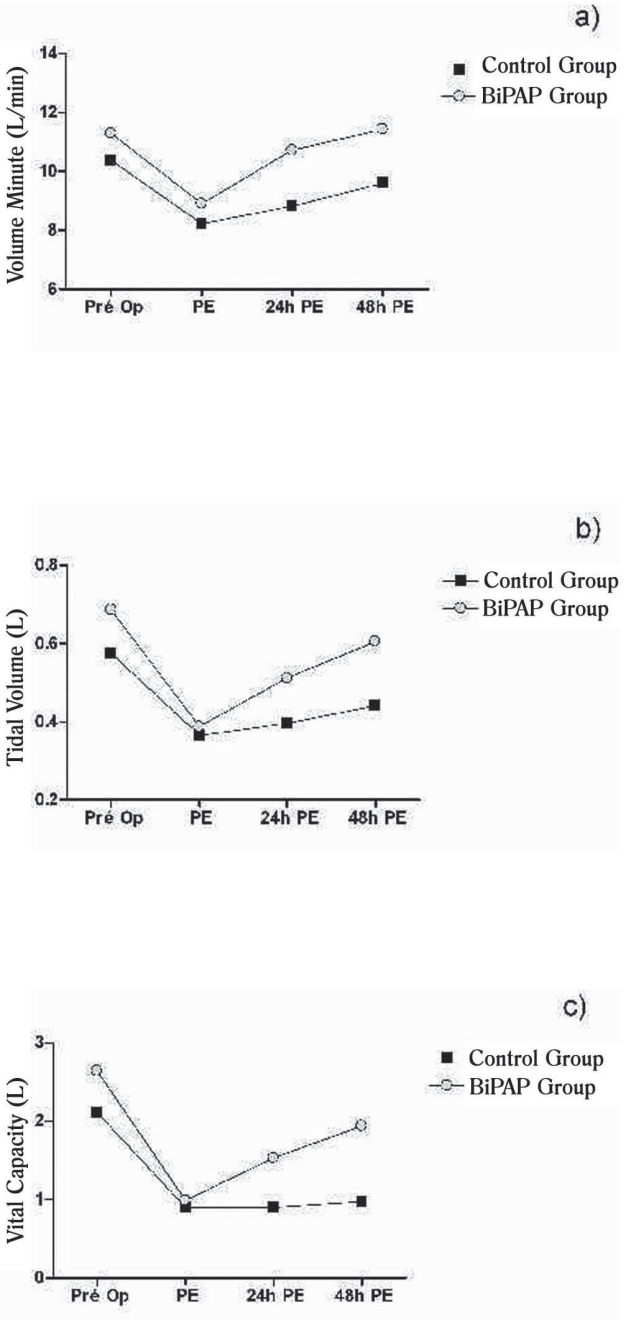

Fig. 1 - A: Distribution of the changes in Minute Volume Preoperatively, immediate postextubation, 24 and 48 hours after extubation, on average, in control groups and BiPAP (P <0.001 within groups, P = 0.250 between groups) ; B: Distribution of the changes in tidal volume in the preoperative, immediate post-extubation, 24 and 48 hours after extubation on average in the groups (P <0.001 within groups, P = 0.250 between groups), C: Distribution of the changes of vital capacity preoperatively, immediately after extubation, 24 and 48 hours after extubation on average in the BiPAP and control groups (P <0.001 within groups, P = 0.15 between groups). Pre-op = preoperatively and PE = Post-extubation

Regarding the RR in both groups, a significant increase when comparing the values obtained postoperatively with the preoperative (P <0.001), similarly in both groups. But there was no significant difference between groups (P = 0.265) (Figure 3).

Figure 4 illustrates the behavior of the values of MRR (MIP and MEP), which can be seen that both the MIP and MEP present in both groups, significant drop in their values when compared with those obtained postoperatively with the preoperative period (P <0.001). But there was no significant difference between groups (P = 0.463 and P = 0.843, respectively).

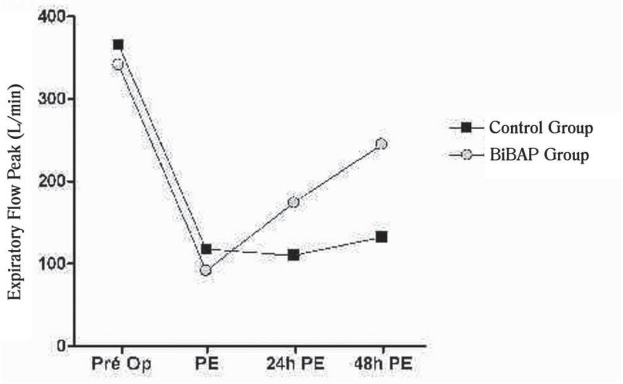

Fig. 2 - Distribution of changes in expiratory flow peak preoperatively, immediately after extubation, 24 and 48 hours after extubation on average in the BiPAP and control groups. Pre-op = preoperatively and PE = Post-extubation. (P <0.001 within groups, P = 0.327 between groups)

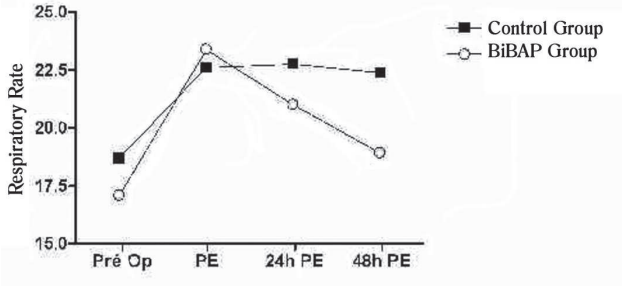

Fig. 3 - Distribution of the changes in respiratory rate in the preoperative, immediate post-extubation, 24 and 48 hours after extubation on average in the BiPAP and control groups. Pre-op = preoperatively and PE = Post-extubation. (P <0.001 within groups, P = 0.265 between groups)

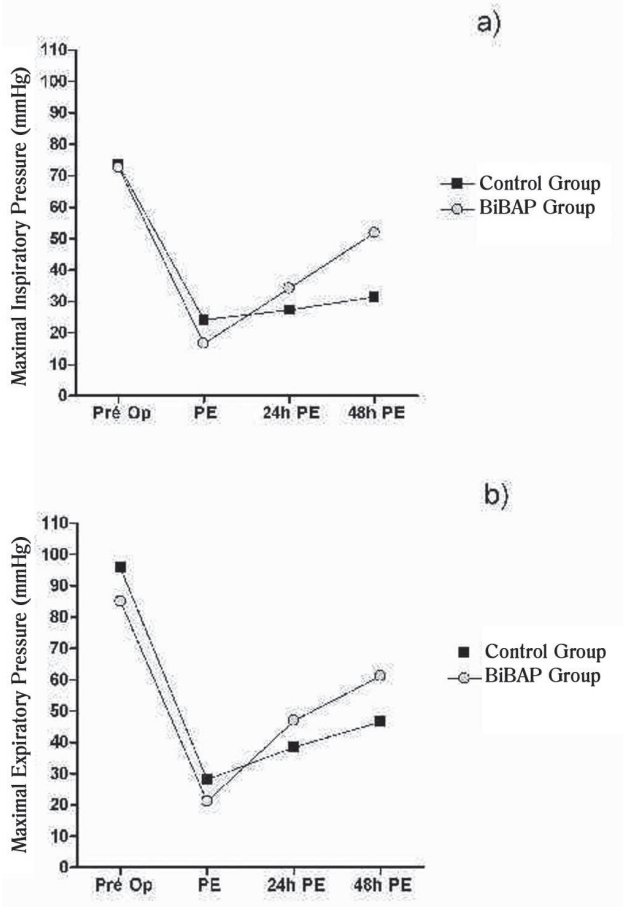

Fig. 4 - A: Distribution of the changes in maximal inspiratory pressure preoperatively, immediately after extubation, 24 and 48 hours after extubation on average in the BiPAP and control groups. Pre-op = preoperatively and PE = Post-extubation. (P <0.001 within groups, P = 0.123 between groups), B: Distribution of changes in maximal expiratory pressure preoperatively, immediately after extubation, 24 and 48 hours after extubation on average in the BiPAP and control groups. Pre-op = preoperatively and PE = Post-extubation. (P = 0.540 within groups, P = 0.056 between groups)

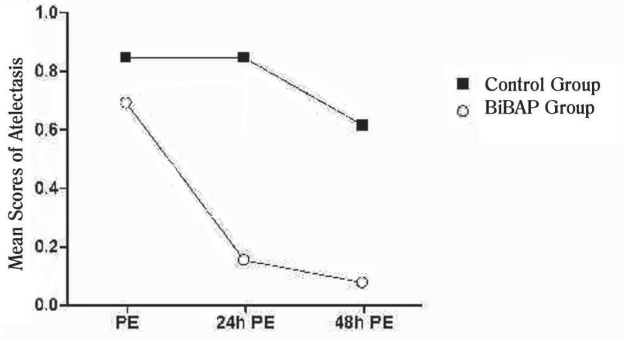

Fig. 5 - Evolution of the mean scores of atelectasis on days 1, 2 and 3 post-operative and control groups in the BiPAP. PO: postoperative. (P = 0.070 within groups, P = 0.080 between groups)

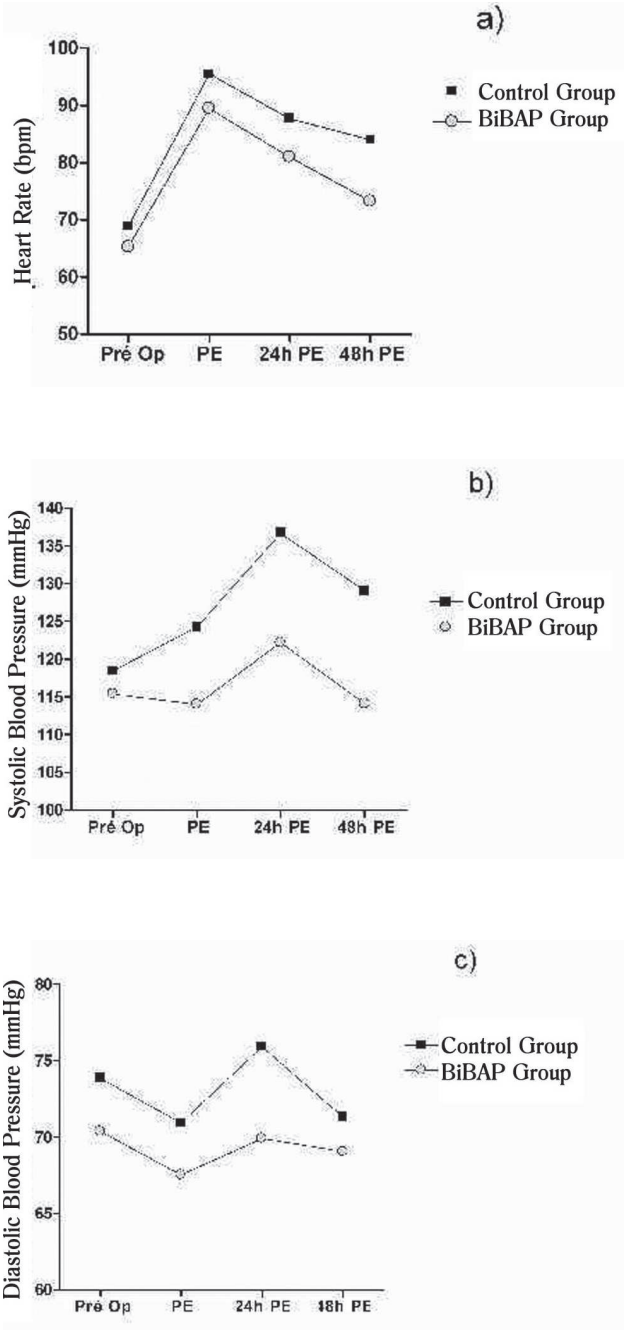

Fig. 6 - The Evolution of Heart Rate measures preoperatively, immediately after extubation, 24 and 48 hours after extubation on average in the BiPAP and control groups. Pre-op: Pre-operative PE: Post-extubation (P <0.001 within groups, P = 0.123 between groups), B: Change in systolic blood pressure measurements preoperatively, immediately after extubation, 24th and 48th hour post- extubation on average in the BiPAP and control groups. Pre-op: Pre-operative PE: Post-extubation. (P = 0.540 within groups, P = 0.056 between groups), C: Changes in diastolic blood pressure measurements preoperatively, Immediate Post-extubation, 24th and 48th in average hours post extubation, BiPAP and control groups. Pre-op: Pre-operative PE: Post-extubation. (P = 0.358 within groups, P = 0.224 between groups)

No patient had radiological findings compatible with atelectasis in the preoperative radiographs. In the control group, 61.5% of patients had some degree of postoperative atelectasis in the group BiPAP ®, the incidence was 54% (P = 0.080). When comparing the degree of atelectasis, the severity score according to the adopted, although we observed a tendency to less severe atelectasis in the BiPAP group, the differences were not statistically significant (*P* = 0.070) (Figure 5).

The evolution of measures of heart rate, systolic and diastolic blood pressure preoperatively, immediately after extubation, 24th and 48th hours after extubation, on average, the BiPAP and control groups is shown in Figure 6.

DISCUSSION

The NIV administered continuously or intermittently has been used alone or in combination with physical therapy maneuvers to prevent atelectasis and hypoxemia in the postoperative period of abdominal surgeries, but with conflicting results [30,31].

The patients studied had no radiological findings compatible with atelectasis in the preoperative radiographs. In the control group, 61.5% of patients had some degree of postoperative atelectasis in the BiPAP group, the incidence was 54% (*P* = 0.691). When comparing the degree of atelectasis, the severity score according to the adopted, although they note a tendency to less severe atelectasis in the BiPAP group, the differences were not statistically significant (*P* = 0.070).

Decreased effectiveness of cough, decreased mobility in bed, reduced discharges and airway narrowing and muscle fatigue associated with physiological changes in breathing pattern, diaphragmatic breathing to a more superficial and predominantly thoracic, are responsible for the decrease in the expansion of lower lung lobes [32]. Lung damage in reinsufflation may culminate in the continuation or worsening of the situation, encouraging the development of pneumonic processes [33].

It was verified in this study that the peak expiratory flow in the BiPAP group had an average value at the 48th hour of 244.62, while the control group the average was 132.31, but there was no significant difference between groups. We believe that the increase in the raid chest with the use of BiPAP® improves the effectiveness of cough, increasing discharges and, consequently, the permeability of the airways, improving the values of flow peak.

The ventilation of patients undergoing this type of surgery is impaired due to the shallow breathing and low-amplitude in an attempt to minimize the pain. It was found that statement, because the tidal volume and vital capacity in the postoperative moments immediate postoperative

period, 24th and 48th hours were lower than the preoperative in both groups, with statistical significance. Moreover, the vital capacity was statistically different when comparing the two groups, where group means BiPAP preoperatively, immediately after extubation and 24 and 48 hours after extubation were 2.64, 0.99, 1, 53 and 1.94, respectively, and in the control group, the averages were 2.11, 0.90, 0.90 and 0.97, respectively.

In the study by Stell et al. [34], the use of NIV in the postoperative period also contributed to the increase in vital capacity, vital capacity proved to be an important parameter to determine whether the patient has risk of reintubation.

NIV reduces the work of breathing and improves respiratory system compliance by reversing microatelectasis lung [23], and is independent of patient effort to generate deep breaths, so an advantage over other methods, particularly in the immediate postoperative period in which the patient is uncooperative or unable to perform maximal inspiration due to pain, by increasing the values of lung volumes and capacities [24]. However, the acceptance of the proposed treatment of the BiPAP group was better, not because the dependence on patient effort to generate deep breaths, reduces pain during exercise, which is run more efficiently, which creates an advantage over FRC group of individuals who feel more insecure to perform deep breaths.

It is also found that the use of NIV for at least two days after surgery, leads to beneficial effects on pulmonary function and oxygenation indices [7]. In the present study, we observed an increase in pulmonary function parameters measured after 48 hours after surgery.

It is understood, therefore, the statement indicates that the therapeutic application of positive pressure in the first hours after surgery with the goal of restoring lung volume and capacity, and respiratory complications often encountered in postoperative cardiac surgery, and decrease in tidal volume and vital capacity in the first hour is a common finding and can cause serious systemic complications, mainly due to cellular hypoxia.

As for the variable minute volume, there was no significant difference between the two groups, pre-and postoperatively, but the respiratory rate of patients undergoing conventional treatment, despite remaining within the normal range, had higher average values of elevated at 24 hours (respiratory rate of 22.77 rpm) and 48 h (respiratory rate of 22.38 rpm) compared to patients in the group undergoing treatment with BiPAP ®, mean values remained lower at 24 hours (respiratory rate of 21.00 rpm) and 48 h (respiratory rate of 18.92 rpm).

By correlating the values of tidal volume, minute volume and respiratory rate, we can see the interrelationship between them and the form of compensation used by patients in both groups, trying to keep an adequate minute volume. They had significantly lower tidal volume, therefore, adopted a compensatory mechanism, increasing the breathing rate, which was significantly higher.

The peak of postoperative diaphragm dysfunction, a reduction of its strength, occurs in the period between two and eight hours after surgery, returning to preoperative values in 15 days approximately. These changes occur in response to surgery and can progress to respiratory complications when modifying the course originally planned for postoperative recovery. The complications are related to decreased contractile capacity of the diaphragm, directly represented by the reduction of maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) [35,36].

Regarding the results obtained from the MIP in our study, decreased significantly in both groups postoperatively compared to preoperative values. When compared to the control group at the 48th hour, the group submitted the application of BiPAP ® showed improvement in inspiratory muscle function (average of 51.92 for the BiPAP group and 31.54 for the control group), but there was no statistical significance. These results may have been identified as a result of removal of chest tubes, made around 36 hours after surgery, because with the reduction of pain caused by the presence of the drain, the patient has a greater ability to contraction of the respiratory muscles, but the best thoracic mobility to the BiPAP ® due to increased inspiratory capacity allows the diaphragm better amplitude of incursion, which may condition the red fibers of high-oxidative, fatigue resistant, generate higher intrathoracic pressure, resulting in increased MIP.

In relation to the MEP, it behaved similarly to the MIP, with significantly lower in both groups when compared to postoperative values with preoperative values. There was an increase in the average values in the 24 and 48 hours compared to immediate post-extubation time, with no statistical significance between groups, but with higher values for the BiPAP group.

Respiratory muscle strength increases directly with the clinical improvement after surgery, probably by reducing pain in consequence of the removal of drains and the improvement of elastic recoil of the chest through the healing process. After removal of drains, the patient improves the degree of mobility, achieving better posture, decreasing, and hence the degree of respiratory muscle weakness and improving its mechanism of action [37].

The length of ICU stay ranged from 2 to 3 days in both groups. In the BiPAP group only one patient remained three days, while in the control group, four patients remained three days. Already, the average length of hospital stay in the control group was 9.30 days, while in the BiPAP group the average was 7.38 days.

It can be observed that there is a tendency to more rapid improvement of the parameters evaluated in the BiPAP group patients compared to the group of CRF (Figures 1 to 4).

The application of NIV in a preventive postoperative proved to be safe, maintaining stable hemodynamic parameters (Figure 6) and without any other complication, such as vomiting and aspiration, chest discomfort, nasal congestion, pneumothorax, pneumocephalus, pain in sinuses, sinusitis, nasal dryness, subcutaneous emphysema in the lower eyelids, aerophagia and epistaxis.

CONCLUSION

In conclusion, we observed that patients undergoing coronary artery bypass grafting associated with CPB showed losses on lung function, and the use of BiPAP ® associated with postoperative CRF was safe and well accepted by patients and have increased vital capacity.

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