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The effectiveness of positive end-expiratory pressure after coronary artery bypass grafting

Efeitos da aplicação da pressão positiva expiratória final no pós-operatório de revascularização do miocárdio

Los efectos de la aplicación de la presión positiva espiratoria final en el postoperatorio de la revascularización del miocardio

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ABSTRACT | The aim of the study was to evaluate the effects of conventional respiratory physical therapy (CRP) associated with positive end expiratory pressure (PEEP) on pulmonary function, inspiratory muscle strength (IMS) and radiological alterations in patients undergoing myocardial revascularization. A total of 15 patients were selected and divided into 2 groups: Group 1 (n=7) underwent CRP and Group 2 (n=8) underwent PEEP associated with CRP. Pulmonary function was evaluated by spirometry, the IMS, using a manovacuometer and the presence of pulmonary abnormalities was observed using chest radiographs, in the preoperative (Pre) and third postoperative (PO3) periods. Significant reductions were observed in the spirometric values and maximal inspiratory pressure between Pre and PO3 in the 2 groups, and there was no difference in the comparison between groups. In conclusion, the patients suffered impairments in the IMS and pulmonary function after surgery and, even having undergone respiratory therapy protocols, there was no restoration of the values by PO3 or differences between groups, despite the inclusion of PEEP. However, no patients presented radiological changes as a result of the heart surgery.

Keywords | Respiratory Function Tests; Muscle Strength; Physical Therapy Modalities; Myocardial Revascularization.

RESUMO | O objetivo do estudo foi avaliar os efeitos da fisioterapia respiratória convencional (FRC) associada à pressão positiva expiratória final (PEEP) sobre a função pulmonar, força muscular inspiratória (FMI) e alterações radiológicas em pacientes submetidos à revascularização miocárdica. Foram selecionados 15 pacientes, divididos em 2 grupos: GI (n=7), submetidos à FRC e GII (n=8), submetidos à PEEP associada à FRC. A função pulmonar foi avaliada através da espirometria, a FMI através da manovacuometria e foi observada a presença de alterações pulmonares pela radiografia de tórax, nos períodos pré-operatório (Pré) e terceiro pós-operatório (PO3). Observaram-se reduções significativas dos valores espirométricos e de pressão inspiratória máxima entre o Pré e o PO3 nos 2 grupos, e não houve diferença na comparação entre os grupos. Em conclusão, os pacientes sofreram prejuízos na FMI e função pulmonar após a cirurgia e, mesmo submetidos a protocolos de fisioterapia respiratória, não houve restabelecimento dos valores até o PO3 nem diferença entre os grupos, apesar da inclusão da PEEP. Entretanto, nenhum apresentou alterações radiológicas em decorrência da cirurgia cardíaca.

Descritores | Testes de Função Respiratória; Força Muscular; Modalidades de Fisioterapia; Revascularização Miocárdica.

RESUMEN | Esta investigación tuvo como objetivo evaluar los efectos de la fisioterapia respiratoria convencional (FRC) asociada a la presión positiva espiratoria (PEEP) sobre la función pulmonar, fuerza muscular inspiratoria (FMI) y alteraciones radiológicas en pacientes sometidos a la revascularización del miocardio. Se han elegidos 15 pacientes, los cuales se dividieron en 2 grupos: GI (n=7),

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sometidos a la FRC, y GII (n=8), sometidos a la PEEP asociada a la FRC. Se evaluó la función pulmonar a través de la espirometría, la FMI a través del manovacuómetro, y se observó la presencia de alteraciones pulmonares por la radiografía de tórax, en los periodos preoperatorios (Pre) y tercero postoperatorio (PO3). Se observó reducciones significativas de los valores espirométricos y de la presión inspiratoria máxima entre Pre y PO3 en los 2 grupos, y no hay diferencias de comparaciones entre los grupos. En conclusión, los pacientes sufrieron pérdidas en la FMI y en la función pulmonar después de la cirugía y, aunque sometidos a los protocolos de fisioterapia respiratoria, no hubo restauración de los valores hasta PO3 ni diferencia entre los grupos, a pesar de la inclusión de la PEEP. Mientras tanto, ninguno presentó alteraciones radiológicas como consecuencia de la cirugía del corazón.

Palabras clave | Pruebas de Función Respiratoria; Fuerza Muscular; Modalidades de Fisioterapia; Revascularización del Miocardio.

INTRODUCTION

Cardiac surgery (CS) is a procedure used to treat cardiovascular diseases, the performance of which results in a high rate of postoperative complications[1-3]. Highlighted among these are respiratory-related complications, such as reduced oxygenation, pulmonary function, respiratory muscle strength, and radiological changes, namely atelectasis and pleural effusions, which increase the risk of postoperative morbidity and mortality[4-9].

Based on understanding regarding such complications and their possible repercussions, respiratory physiotherapy has been used with a view to reverse or mitigate these types of situations. Studies have shown that any kind of physiotherapeutic intervention is better than non-intervention in the postoperative (PO) period of CS patients[10,11]. Thus, deep breathing exercises have been frequently used during the PO period of CS, with the objective of increasing pulmonary expansion[7,10,12]. When combined with positive end-expiratory pressure (PEEP), these types of exercises can optimize the pulmonary bronchial hygiene, increase arterial oxygenation and improve pulmonary compliance, thereby providing effects such as variation in intra-alveolar pressure, increased functional residual capacity (FRC), extravascular fluid redistribution, decreased intrapulmonary shunt and optimized bronchodilator administration[13].

As a result, there have been studies performed whose purpose was to investigate how physiotherapeutic intervention is applied, whether it be combined or not to positive airway pressure, in order to minimize adverse effects from CS[4,6]. Results from some studies that were found in the literature do not agree with each other, they have no consensus in terms of the effectiveness of using expiratory positive pressure on respiratory function during the PO period of CS. Richter-Larsen, et al.[4] and Bertol, Ferreira and Coronel[14] did not find any significant differences regarding reducing hypoxemia, atelectasis or improved forced vital capacity (FVC) among patients treated with conventional respiratory physiotherapy, (CRP) associated with PEEP, or those only treated with FRC in the PO period of CS. However, there are reports from studies that observed a reduction in atelectasis incidence, pulmonary values returning to normal[6,7] and inspiratory muscle strength[9] during the application of PEEP in the PO period of CS.

Based on the aforementioned, the aim of this study was to evaluate the effects of CRP associated to PEEP on pulmonary function, respiratory muscle strength and radiological changes in patients undergoing myocardial revascularization (MR) with cardiopulmonary bypass (CPB).

METHODOLOGY

Sample

While adhering to rules regarding experimental conduct with humans, this study followed the guidelines from resolution 196/96 of the Brazilian National Health Council. The study was approved by the Ethics Committee and research with Human Beings from the Universidade Metodista de Piracicaba (protocol Nº. 75/09) and all volunteers had signed an informed consent form.

18 patients were recruited, however only 15 completed the study, this was due to hemodynamic instability (n=2) and difficulty in executing the maneuvers during the assessment in the PO period (n=1). All the

patients were male, between the ages of 30 and 60 years, had underwent myocardial revascularization with CPB and had been admitted to the Cardiac Intensive Care Unit at the *Fornecedores de Cana de Piracicaba* Hospital (*HFCP*). Patients were selected from the weekly surgical schedule. The patients were randomly gathered into two groups: GI (n=7) were submitted to conventional respiratory physiotherapy, and GII (n=8) were submitted to the expiratory positive pressure in the airways associated to CRF.

The inclusion criteria for the study were: coronary insufficiency diagnosed through bone scans and confirmed by catheterization, elective surgical myocardial revascularization with CPB, clinical and hemodynamic stability. Exclusion criteria consisted of: hemodynamic instability, obstructive or restrictive ventilatory pattern evaluated by spirometry, neuromuscular diseases, development of postoperative respiratory disease or difficulty in understanding procedures.

Evaluation

Pulmonary function test

Pulmonary function tests were performed using a 2001 Easy one™ computerized ultrasonic spirometer with flow sensor (ndd Medizintechnik AG, Zurich, Switzerland), with internal Winspiro software updated to version 1.04. The forced vital capacity (FVC) maneuver was performed in the preoperative and third postoperative (PO3) period. Each maneuver was performed until 3 acceptable and 2 reproducible curves were achieved, not exceeding 8 attempts.

During the tests, the patients remained seated, with their nostrils occluded by a nasal clip. The technical procedures, criteria for acceptability and reproducibility were performed in accordance with the standards recommended by the *American Thoracic Society*[15].

Inspiratory muscle strength

Inspiratory pressure, generated at the mouth level, was measured in the preoperative and PO3 period, using an MVD 300 digital manovacuometer (GlobalMed, RS, Brazil), escalated in cmH_2O.

These measurements were performed while the patients were sitting and had their nostrils occluded by nasal forceps. The maximal inspiratory pressure (IP_{max}) was measured during the force beginning from the residual volume (VR)[16,17]. All patients executed at least three technically satisfactory maximal inspiration efforts, i.e. with no air leakage and values close to each other (≤10%), and the measurement of greatest value was considered for this study. The inspiration was maintained for at least 1 second[17]. In order to avoid high pressure in the oral cavity, an oral-adapted device with a hole, which was 2mm in internal diameter and 1.5mm in length, was used.

Chest radiography

From the preoperative period up to discharge from hospital, all patients underwent daily chest x-rays in anteroposterior incidence, this was done so as to follow up clinical evolution. The test reports were noted in each patient's medical board by the responsible researcher, who looked for atelectasis, pulmonary consolidations, pleural effusion and collapsed lung.

Protocols

Physiotherapeutic treatment was initiated during the immediate postoperative period, with mechanical ventilation weaning and orotracheal extubation, and continued until the patient was discharged from hospital.

- Conventional Respiratory Physiotherapy (CRP)

CRP consisted of maneuvers for bronchial hygiene, through oral high frequency oscillation (OOAF; Shaker®, NCS, São Paulo, Brazil) or Acapella (Choice®, DHD Healthcare Corporation, Knoxville, USA), assisted coughing, diaphragmatic respiratory exercises, respiratory functional reeducation (deep inspiration exercises and inspirations fractionated into 2 and 3 times) and respiratory exercises associated with upper limb movement. Active-assisted exercises of the extremities (flexion-extension and rotations with the upper and lower limbs) were also performed. Physiotherapy sessions were held twice a day for 5 days, totaling 10 sessions. Breathing and motor exercises were performed in 3 sets of 10 repetitions.

- Therapy with positive end-expiratory pressure (PEEP)

After completing their CRF, patients from GII were subjected to PEEP, using adult expiratory positive airway pressure (EPAP) devices (CriticalMed, Rio de Janeiro, Brazil), through exhaling into a mouthpiece connected to a one-way valve, with a spring loaded

extrinsic PEEP valve at its end, without any perioral air leakage. The load adjustment varied between 5 and 10cmH_2O, due to the difficulty that some patients had in achieving the stipulated maximum load, with it being necessary, in these cases, to decrease it. three sets of 20 repetitions were performed twice a day.

Data processing

The SPSS 13.0 application was used for the statistical analysis. The Shapiro-Wilk test was used to analyze the data distribution, which did not show a normal distribution. Thus, the Wilcoxon test was used for paired analysis and the Mann-Whitney test for non-paired analysis. A value of $p<0.05$ was considered as being statistically significant.

The sample calculation was based on the standard deviation obtained during a pilot study conducted by the responsible researcher, in which pulmonary function was evaluated in 10 male patients in their PO period of CS, with the forced vital capacity variable being used. Based on the establishment of a 5% significance level and an 80% power test, the suggested sample size was 10 subjects per group. The GraphPad StatMate 2.0 Windows application was used for the statistical calculation.

RESULTS

Table 1 shows the studied groups' characteristics in the preoperative condition, in regards to age, anthropometry, cardiopulmonary bypass time, hospitalization time and radiological changes. There were no significant differences observed between the groups.

Table 1. Characteristics of the studied patients (mean±standard deviation)

Characteristics	GI (n=7)	GII (n=8)	p
Age (years)	56.9±12.8	62.1±2	0.74
Body mass (kg)	78.1±9.5	76.2±10.1	0.70
Height (cm)	171±8.8	171.3±7.0	0.85
BMI (kg/m²)	26.8±3.2	26±3.8	0.85
CPB time (minutes)	75.8±17.1	83.6±8.3	0.41
Hospitalization length (days)	6.3±1.7	6.1±1.4	0.84
Radiological changes	no	no	-

GI: Group I; GII: Group II; BMI: body mass index; CPB: cardiopulmonary bypass

As regards the values of the maximal inspiratory pressure (IP_{max}), there were significant differences between the preoperative and the PO3 period, for GI and GII, these being the lowest values found in the postoperative period. No significant difference was observed while comparing the two groups (Figure 1).

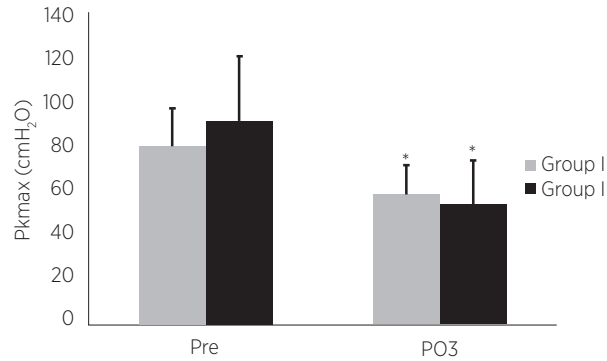

Figure 1. Values for maximal inspiratory pressure (IP_{max}) in the studied groups

* p<0.05 Pre vs PO3

IP_{max}: maximal inspiratory pressure; PO3: third postoperative period; Pre: preoperative period

During the pulmonary function analysis, the spirometric values showed significant differences between the preoperative and the PO3 period; in both groups, there were no differences observed when the two groups were compared (Figure 2).

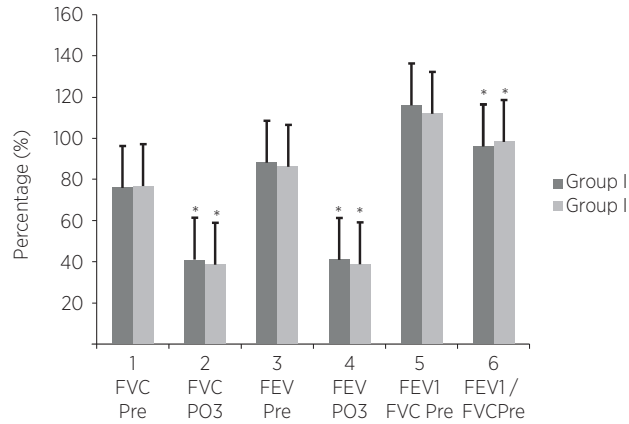

Figure 2. Spirometric values for the study groups

* p<0.05 Pre vs PO3

Pre: postoperative; PO3: third postoperative period; FVC: forced vital capacity; FEV_1: forced expiratory volume in the first second; FEV_1/FVC: ratio between forced expiratory volume in the first second and forced vital capacity

DISCUSSION

This study's main findings showed there to be reduced inspiratory muscle strength and pulmonary function in both the studied groups, when compared to the preoperative and PO3 conditions, with these being the smallest values observed following surgery. There were no observed radiological changes in the postoperative period.

Those patients who were underwent CS developed pulmonary changes in the PO period due to diaphragmatic dysfunction, pain in the surgical incision and residual anesthetic effects[6-8,18,19]. CPB may promote systemic inflammatory response syndrome[20,21], thereby accentuating respiratory impairment. Considering these changes, one better clarification becomes relevant in terms of postoperative methods that can minimize such changes, in addition to encouraging respiratory function restoration in these patients.

Various physiotherapeutic procedures are described in the literature which minimize the respiratory complications that arise from CS. However, no consensus exists regarding the effectiveness and superiority between the methods used. In a study performed by Zangerolamo, et al.[22], there were no significant differences were found between the practice of conventional physiotherapy and that associated with incentive spirometry, as was the case with Freitas, et al.[23], who did not observe any restoration of pulmonary function after the physiotherapeutic intervention during the PO period of CS. In spite of the protocols used during this study having shown differences, this research also concluded that there using a respiratory physiotherapy device with positive pressure is in no way better compared to conventional physiotherapy in re-establishing respiratory function in the PO period of CS.

During studies carried out by Richter-Larsen, et al.[4] and Bertol, Ferreira and Coronel[14] there were no significant observed differences in terms of reducing hypoxemia, atelectasis and improving forced vital capacity (FVC) among patients treated with CRF and PEEP, or in those only treated with CRF in the PO period of CS, which is consistent with the results found during this study, where there was no observed improvement of the FVC. However, there was no observed hypoxemia or atelectasis in either groups, in addition to no patient having been excluded as a result of respiratory complications.

In a study developed by Borghi-Silva, et al.[6] with patients in the PO period of MR, it was observed that the group who underwent CRF associated to PEEP showed a restoration in their pulmonary function and inspiratory muscle strength up to the 5th PO period. Stein, et al.[24] found a significant positive correlation between respiratory muscle strength and functional capacity, evaluated by means of the 6-minute walk test, in patients undergoing CRF and associated to PEEP in the PO period of CS. In contrast, this study found no improvements in the spirometric values or in inspiratory muscle strength during the postoperative period following the physiotherapeutic intervention. The discrepancy might be explained by the difference in the applied protocols and evaluation periods. This study only involved patients who began walking after being discharged from the cardiac ICU and were reassessed during the PO3 period, since some of them were discharged during the fourth postoperative period (PO4).

Upon comparing the spirometric values and the respiratory muscle strength obtained between the preoperative and the PO3 period, it was noted that it was not possible to restore the initial values, even after the interventions. These results can be explained by the patients' short hospitalization period and by the duration time of the postoperative clinical ailments. Some authors report that these ailments may be present up to the 6th PO[25] or 15 days after the surgical procedure[26], whereas Craig[27] report that the FVC is reduced for ten to fourteen days and according to Westerdahl, et al.[7], the FEV_1 remains reduced for up to four months after CS in patients who only performed CRF.

Respiratory complications present in the PO period of CS are frequent, especially atelectasis, pneumonia, pleural effusions and hypoxemia[28,29]. CS is known to promote changes in the ventilatory mechanics, respiratory muscle strength and pulmonary function[19,30] and thus can contribute to there being respiratory complications. In this sense, Westerdahl, et al.[7] found that using PEEP promoted lower incidence of atelectasis, and smaller reductions in some spirometric values in patients submitted to MR, when compared to those who had not undergone respiratory physiotherapy.

This study did not involve a group who did not receive intervention due to ethical issues and the hospital's physiotherapeutic care routine. However, despite there not having been any significant observed increases in respiratory muscle strength or pulmonary function after the proposed intervention protocols, it is possible to hypothesize that they were capable of preventing pulmonary complications such as atelectasis and pleural effusions, given that none of the volunteers studied presented radiological complications, nor did they show any other ailments related to pulmonary complications arising from CS. The findings corroborate those made by Raid, et al.[31], which did not observe any relationship between respiratory muscle strength behavior and respiratory complications in the PO period of CS, even following physiotherapeutic intervention.

CONCLUSION

Patients undergoing MR with cardiopulmonary bypass suffered losses in respiratory muscle strength and pulmonary function and, even those subjected to respiratory physiotherapy protocols, showed no re-establishment of the values of these variables up to the PO3 period, nor was there any difference between the groups, despite PEEP being included. However, there were no patients who showed any radiological changes as a result of CS.

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