ORIGINAL RESEARCH

THE INFLUENCES OF POSITIVE END EXPIRATORY PRESSURE (PEEP) ASSOCIATED WITH PHYSIOTHERAPY INTERVENTION IN PHASE I CARDIAC REHABILITATION

Audrey Borghi-Silva, Renata Gonçalves Mendes, Fernando de Souza Melo Costa, Valéria Amorim Pires Di Lorenzo, Claudio Ricardo de Oliveira, and Sérgio Luzzi

Borghi-Silva A, Mendes RG, Costa F de SM, Di Lorenzo VAP, Oliveira CR de, Luzzi S. The influences of positive end expiratory pressure (PEEP) associated with physiotherapy intervention in phase I cardiac rehabilitation. Clinics. 2005;60(6):465-72.

PURPOSE: To evaluate the effects of positive end expiratory pressure and physiotherapy intervention during Phase I of cardiac rehabilitation on the behavior of pulmonary function and inspiratory muscle strength in postoperative cardiac surgery.
METHODS: A prospective randomized study, in which 24 patients were divided in 2 groups: a group that performed respiratory exercises with positive airway expiratory pressure associated with physiotherapy intervention (GEP, n = 8) and a group that received only the physiotherapy intervention (GPI, n = 16). Pulmonary function was evaluated by spirometry on the preoperative and on the fifth postoperative days; inspiratory muscle strength was measured by maximal inspiratory pressure on the same days.
RESULTS: Spirometric variables were significantly reduced from the preoperative to the fifth postoperative day for the GPI, while the GEP had a significant reduction only for vital capacity ($P < .05$). When the treatments were compared, smaller values were observed in the GPI for peak flow on the fifth postoperative day. Significant reductions of maximal inspiratory pressure from preoperative to the first postoperative day were found in both groups. However, the reduction in maximal inspiratory pressure from the preoperative to the fifth postoperative day was significant only in the GPI ($P < .05$).
CONCLUSIONS: These data suggest that cardiac surgery produces a reduction in inspiratory muscle strength, pulmonary volume, and flow. The association of positive expiratory pressure with physiotherapy intervention was more efficient in minimizing these changes, in comparison to the physiotherapy intervention alone. However, in both groups, the pulmonary volumes were not completely reestablished by the fifth postoperative day, and it was necessary to continue the treatment after hospital convalescence.

KEYWORDS: **Cardiac surgery. Pulmonary function. Respiratory muscle strength. Physiotherapy. PEEP.**

Cardiac surgery reverts symptoms for individuals with specific cardiopathologies and measurably increases their chances of survival and quality of life.[1–3] However, pulmonary complications are quite frequent and represent an important cause of morbidity and mortality for patients undergoing cardiac surgery with cardiopulmonary bypass.[2,4-6]

Cardiology Unit, Santa Casa de Misericórdia de Araraquara
Email: audrey@power.ufscar.br
Received for publication on July 29, 2005.
Accepted for publication on September 19, 2005.

These patients can develop various degrees of a systemic inflammatory response syndrome due to factors such as surgical trauma, contact of blood with nonendothelial surfaces of the bypass circuit, and alterations known as reperfusion post-cardiopulmonary bypass lesions, mainly affecting the cardiac and pulmonary regions.[2,4–6]

In the pulmonary region, there is an increase in extravascular water with alveolar filling caused by inflammatory cells, which leads to the inactivation of the pulmonary surfactant and collapse of some areas, modifying the pulmonary ventilation/perfusion relationship, with resultant increases in the respiratory effort during the postoperative (PO) period.[7,8]

In spite of modernization of procedures, cardiac surgery can damage pulmonary function, with decreases of respiratory muscle strength and spirometric measurements occurring postoperatively, in addition to the occurrence of atelectasis in more than 90% of the patients.[9]

Reduction in oxygenation,[10] pulmonary function,[11,12,13,14] and respiratory muscle strength,[4,5,9,12] as well as radiological changes such as atelectasis[8,12,15] have been cited as common alterations in postoperative cardiac surgery. The reduction of respiratory muscle strength, resulting from direct or indirect lesion of respiratory muscles during surgery and the secondary diaphragmatic dysfunction due to phrenic nerve lesion, has also been related to reduced pulmonary function tests, worsened gas exchange, and increase in the rate of pulmonary complications.[4,5,9,12] Considering this, some authors[8,15-19] have investigated the application of different physiotherapeutic treatment techniques in an attempt to minimize the alterations in the respiratory and cardiovascular system and thereby reduce the incidence of complications.

Physiotherapy intervention in phase I of cardiac rehabilitation (PPI) is routinely performed with patients who have undergone cardiac surgery.[11,13,18,19] The application of deep breathing exercises, cough stimulation, thumping and vibration of the rib cage, and continuous positive airway pressure may prevent further deterioration in pulmonary function and reduce the incidence of pulmonary complications.[18] However, Jenkins et al.[19] observed that deep breathing exercises, thumping and vibration of the rib cages, and cough stimulation did not result in significant increases in spirometric measurements when compared to the control group.

With the identification of communication between the respiratory bronchioles in human lungs, some authors have concluded that collateral ventilation is important in normal pulmonary function[17] and thereby confirm that the application of positive end-expiratory airway pressure (PEEP) can promote a more homogenous distribution of pulmonary ventilation through interbronchial collateral channels and prevent expiratory collapse.[17] Thus, PPI associated with the application of PEEP through a circuit of expiratory positive airway pressure (EPAP) using a face mask coupled to a PEEP valve could be effective in minimizing complications that occur postoperatively after cardiac surgery.

Campbell et al.[20] found that PEEP assists with the removal of secretions from the main bronchi, which can be expectorated, in those hypersecretive patients who undergo upper abdominal surgery. In a study by Larsen et al.,[15] the tendency for reduced complications was observed in a group that was administered PPI associated with PEEP, when compared to a group treated only with PPI. However, in another study, the prophylactic application of PEEP did not present benefits when compared to PPI in patients who had undergone thoracic surgery.[16]

In view of the conflicting results of these studies, the objective of this study was to investigate the efficacy of the association of PEEP with a protocol of physiotherapy intervention in Phase I of cardiac rehabilitation, through the evaluation of pulmonary function and inspiratory muscle strength in patients who had undergone elective cardiac surgery.

MATERIALS AND METHODS

This study was approved by the Ethics Committee for Human Research of the institution. The patients were informed about the procedures to be carried out, and all signed an institutionally reviewed informed consent form agreeing to participate in the study in accordance with the Brazilian National Health Council Resolution 196/96.

Thirty patients were recruited for participation, but only 24 patients concluded the study. The patients included in this study presented coronary insufficiency diagnosed by coronary angiography. These patients underwent elective cardiac surgery with cardiopulmonary bypass, and the surgical incision utilized was sternotomy. All patients received medical prescriptions for the physiotherapy procedures. Patients who presented hemodynamic instability, associated neurological sequelae, or difficulty in comprehension or adherence to the procedures performed in this study were excluded.

Patients were randomly distributed into 2 groups in a 1:2 proportion, as follows: 1. a group in which EPAP associated with PPI was performed after cardiac surgery (GEP, n = 8) and 2. a group receiving physiotherapy intervention only (GPI, n = 16) The anthropometrical, clinical, and surgical characteristics of the groups are presented in the Table 1.

Experimental Procedure

In the preoperative period, all the patients underwent a standardized evaluation that consisted of personal data, anthropometrics, medical diagnosis, vital signs, and personal antecedents. The body mass index (BMI) was calculated as:

$$BMI = \text{body weight (kg)}/[\text{height(cm)}]^2$$

Postoperative length of hospitalization, total duration of the surgical procedure, duration of ischemia, and cardiop-

Table 1 - Anthropometrics, clinical, and surgical characteristics of the population studied (mean ± SD)

	GEP (n = 8)	GPI (n = 16)	*P* value
Age (years)	59.9 ± 9.8	55.9 ± 11.9	.24
Weight (kg)	70.2 ± 12.3	64.5 ± 10.1	.14
Height (m)	1.7 ± 0.1	1.6 ± 0.1	.09
Body mass index (BMI) (kg/m^2)	24.7 ± 3.0	24.1 ± 3.0	.30
Surgery time (min)	170.7 ± 32.1	188.7 ± 43.9	.19
Cardiopulmonary bypass time (min)	70.1 ± 17.7	89.2 ± 25.9	.06
Duration of ischemia (min)	64.1 ± 28.9	56.2 ± 20.7	.44
Hospitalization (days)	6.6 ± 1.0	8.0 ± 2.1	.09

ulmonary bypass surgery time were recorded. Heart rate (HR) and peripheral saturation of oxygen (SpO_2) were monitored and recorded during the procedures with a portable pulse oximeter (Nonim 8500A, Plymouth, Mn., USA).

After an initial evaluation, all patients were informed of the proposed protocol, surgical procedure, tracheal intubation, course of treatment, and the importance of physiotherapy for recovery during hospitalization. This was followed by pulmonary function and respiratory muscle strength evaluations.

<u>Pulmonary function test</u>: Spirometry was performed using the Vitalograph® Hand-Held 2120 spirometer (Ennis, Ireland). During the pulmonary function tests, patients remained in the sitting position, with the nostrils occluded by a noseclip, while the maneuvers of vital capacity (VC) and forced vital capacity (FVC) were performed. The technical procedures, acceptable criteria, and reproducibility followed American Thoracic Society guidelines.[21] Measurements for VC, FVC, PF, and FEF25-75% were obtained, and these values were analyzed as percentages of predicted values. Reference values from Knudson et al.[22] were used. The results obtained were expressed in BTPS (liters at body temperature and pressure saturated with water vapor).

<u>Inspiratory Muscle Strength (IMS)</u>: To measure IMS, a manovacuometer Ger-Ar (SP-Brazil) was used, with a scale varying from 0 to 150 cm H_2O, according to the methodology proposed by Black & Hyatt.[23] The maximal respiratory pressures were assessed by maximal inspiratory pressure (MIP) at residual volume. Using a noseclip, patients were asked to produce maximal efforts against an obstructed mouthpiece with a small leak to prevent patients from closing their glottis during the maneuver. Patients sustained maximal effort for 1 second, and the best of 3 consecutive attempts was used.

The 2 groups were reevaluated regarding pulmonary function on the fifth postoperative day (5th PO) and regarding the inspiratory muscle strength at the 1st PO and 5th PO. The evaluations described above were performed by the same professional, with the patient in the sitting position.

Proposed Treatments

Physiotherapy intervention in phase I of cardiac rehabilitation. (PPI)

The patients underwent 2 physiotherapeutic interventions dailyeach lasting approximately 40 minutes, from the immediate postoperative day (IPO) until hospital discharge. The physiotherapeutic sessions carried out were elaborated according to the following protocol:

IPO: Weaning from mechanical ventilation assistance, thumping and vibrating patients' rib cages (airway clearance maneuvers), endotracheal tube aspiration and extubation, which occurred at a maximum of 12 hours after surgery.

1st PO: Airway clearance maneuvers in the prone position; cough assist with the head of bed inclined at 45° (approximately 10 min), respiratory diaphragmatic exercises (3 series of 20 repetitions), inspiration in three stages (2 series of 20 repetitions) of room air, assisted active exercises of the extremities (ankles and wrists, 3 series of 10 repetitions);

2nd PO: Airway clearance maneuvers in prone and semilateral positions and cough assist in a sitting position (approximately 10 min); respiratory diaphragmatic exercises (3 series of 20 repetitions) and inspiration in three stages (2 series of 20 repetitions) in a sitting position. In addition, the following assisted active exercises of upper and lower limbs associated with respiration were performed: 1) flexion-extension of the elbow and elevation of the arms, respecting the articular amplitude range and pain tolerance (2 series of 10 repetitions for each exercise); 2) flexion-extension of the knee, respecting articular amplitude and pain tolerance (2 series of 10 repetitions for each exercise);

3rd PO: Airway clearance maneuvers in a semilateral position (approximately 10 minutes), cough assist in a sitting position, and the respiratory exercises described for the 2nd PO. The following active free exercises of upper and

 CLINICS 2005;60(6):465-72

lower limbs of items 1 and 2 associated with respiration were performed; maintaining an orthostatic position and walking in place for a 5-minute period.

4th PO: Airway clearance maneuvers when necessary and cough assist (approximately 10 min); respiratory exercises, exercises of the upper and lower limbs (as in the protocol for the 2nd PO). During this phase, all the patients were in the medical ward, and walking was performed in the corridor for 10 minutes.

5th PO: The protocol for the 4th PO. Walking in the hospital corridor for 10 minutes, and walking up and down 1 flight of stairs.

Expiratory Positive Pressure in Airways (EPAP)

The application of PEEP was performed through an EPAP circuit using a facial mask coupled to a unidirectional valve containing, at its extremity, a PEEP valve of 10 cm H_2O[15,24] for all patients in the GEP. This group performed 60 repetitions of respiratory exercises divided into 3 series of 20 respirations in 2 daily sessions until discharge from the hospital. The patient inhaled room air through the mask, without additional oxygen, and exhaled against the referred resistance. The patients in this group also went through the PPI protocol after the EPAP exercises, in accordance with the standard hospital physiotherapy treatment routine.

Data Analysis

Based on the means and standard deviations of data for the spirometric variables, a power size calculation was performed with *Graphpad StatMate* version 1.01, 1998. This revealed that a power of 80% and a significance level of 5% would be obtained. To verify the data distribution, data was plotted on a gaussian curve and did not distribute according to a normal distribution. Therefore, for matched-pair comparisons, the nonparametric Wilcoxon test and the Friedman test for matched variables (MIP) were used; the Dunn test was used for differentiation between conditions. For comparison between groups, the Mann-Whitney test was used. The level of significance was set at $P \leq .05$.

RESULTS

From a total of 30 eligible patients, only 24 patients constituted the final research study population of 15 men (62.5%) and 9 women (37.5%), aged 57 ± 11 years. Of the 6 patients excluded from the study, 2 presented hemodynamic instability and were not released by the medical team for spirometric and respiratory strength measurement, 1 presented neurological sequelae, 2 presented difficulties in performing the spirometric test and exhibited a comprehension deficit, and 1 refused to continue the treatment. Table 1 shows the age, weight, height, IMC, duration of surgery, hospitalization, and perfusion of the patients included in this study. No significant differences were found in the anthropometric parameters, clinical, or surgical aspects between the groups analyzed.

Concerning angina, in the GEP, 25% were functional class III and 75% were functional class IV; for the GPI, 31.2% were functional class III and 68.8% were class IV, according to Campeau.[25] Concerning drains, 87.5% of the GEP patients and 81.2% of the GPI patients used the subxiphoid drain, in addition to the mediastinal drain applied to all patients in the postoperative recovery. Of the total grafts, 85% were performed with the left internal thoracic artery plus saphenous vein, and 15% with the radial arteries plus saphenous vein or only the saphenous vein.

The spirometric results obtained in preoperative and 5th PO are presented in Table 2. No differences were found between preoperative spirometric variable values for the groups studied. However, it can be observed that for all spirometric values, previous values for the GPI were not reestablished by the 5th postoperative day, while for the GEP, only VC did not return to its preoperative values ($P < .05$). Intergroup analysis revealed a significant difference only in PF, with greater values for the GEP when compared to the GPI postoperatively.

Inspiratory muscle strength, evaluated through MIP values, was significantly reduced on the 1st PO for both groups studied, with MIP increasing from the 1st PO to 5th PO only

Table 2 - Spirometric variables in the preoperative and postoperative treatment (5th PO) with statistical results for intra- and inter-groups (mean ± SD)

	GEP			GPI		
	Preoperative	5th PO	P value	Preoperative	5th PO	P value
VC (%)	84.7 ± 21.2	57.6 ± 16.8	.0078*	71.5 ± 21.6	53.6 ± 19.4	.0006*
FEV_1(%)	73.6 ± 23.8	57.4 ± 14.1	.1094	70.5 ± 19.3	46.3 ± 28.2	.0001*
FEF_{25-75}(%)	57.1 ± 37.1	34.0 ± 21.0	.1563	54.3 ± 17.8	38.3 ± 20.8	.0015*
FVC (%)	83.1 ± 24.4	67.4 ± 23.8	.1094	83.0 ± 38.0	49.3 ± 16.0	.0004*
PF (%)	69.1 ± 37.9	62.8 ± 13.2	.4063	64.0 ± 26.0	40.5 ± 21.9	.0020*.0189†

*: Differences between conditions; †: Differences between groups; %: predicted; VC: vital capacity; FEV_1: forced expiratory volume in one second; $FEF_{25-75\%}$: forced expiratory flow from 25 to 75 percent of FVC; FVC: forced vital capacity; PF: peak flow

in the GEP. However, in the GPI, significant reductions are observed when comparing preoperative to 5th PO values. In relation to intergroup analysis, greater values of MIP were found on the 1st PO and 5th PO for the GEP compared to the GPI ($P < .05$). Figure 1 illustrates the behavior of this variable for inspiratory muscular strength.

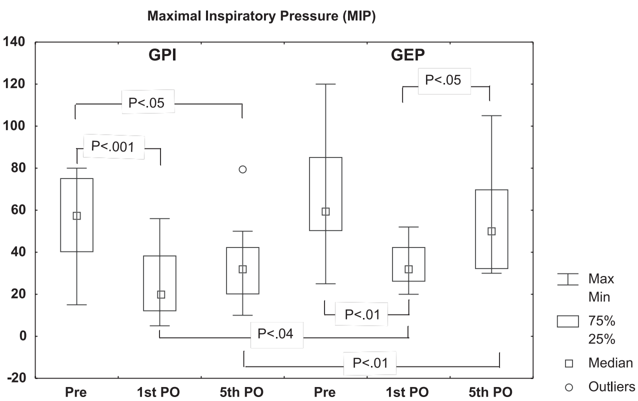

Figure 1 - Maximal inspiratory pressure (MIP) at preoperative (pre), 1st postoperative (1st PO) and 5th postoperative (5th PO) day for the groups studied. (*$P < .05$)

DISCUSSION

Patients undergoing cardiac surgery with cardiopulmonary bypass were studied to determine the effects of a physiotherapy intervention in phase I of cardiovascular rehabilitation, associated or not with the application of PEEP on pulmonary and inspiratory muscular strength.

Alterations in pulmonary function can be associated with various factors such as the type of surgical incision,[26] the anesthetic modality employed,[27] diaphragmatic dysfunction,[27] postoperative pain,[26] and the positioning of the pleural drain.[11] In the present study, all the patients were operated through a sternotomy with the thoracic drain positioned in the subxiphoid (pleural and/or mediastinal) region, which minimized the possible differences that might result from the procedure.

Additionally, some authors have demonstrated that a large number of patients who undergo cardiac surgery with cardiopulmonary bypass present alterations in pulmonary functions in postoperative evaluations.[10,12] Therefore, the performance of procedures to improve their recovery becomes necessary in an effort to minimize the deleterious effects on pulmonary function and of immobility.

Alterations in pulmonary function after cardiac surgery were observed in this study, in agreement with other findings, which supports that a reduction in functional residual capacity (FRC)[27], VC,[13,14,23,28,29] and expiratory flows[11, 13,14] occurs following cardiac surgery. According to published studies, the FVC presents a general reduction for a minimum period of 10 to 14 days.[28,30] In the present study, the FVC was analyzed until the 5th day PO, and no difference was found between the preoperative level and that for 5th PO in the GEP, indicating this variable had returned to previous values. However, in the GPI, in which only PPI was performed to the 5th PO, the FVC was not reestablished. These results corroborate those reported by Guizilini et al.[11] in patients who underwent cardiac surgery without cardiopulmonary bypass.

Westerdahl et al.[13] evaluated pulmonary function up to 4 months after cardiac surgery in patients who did PPI and found that VC and FEV_1 were still significantly reduced when compared to preoperative values. In the present study, the only preoperative measurements reestablished by the 5th postoperative day occurred for the GEP that is, when EPAP was associated with PPI.

The importance of a postoperative physiotherapeutic intervention protocol for cardiac surgery has been justified by some authors in that it can lower the incidence of pulmonary complications brought on by reductions in spirometric measurements.[13,18] Additionally, the application of PEEP has been shown to be effective in increasing the return to pulmonary volumes and the resolution of atelectasis.[17]

Differing from findings in our study, Larsen et al. ,[15] found no difference between the group treated with PPI plus EPAP and the group treated with PPI alone. However, a tendency for the reduction of complications was observed in the group that received PEEP. Ricksten et al.[29] concluded that the administration of EPAP or continuous positive airway pressure was superior to PPI regarding gas exchange, the preservation of pulmonary volumes, and the prevention of atelectasis, in accordance with the findings of the present study, although those findings were from postoperative abdominal surgery patients.

In another study, the application of PEEP did not confer additional prophylactic benefits regarding atelectasis and the reduction of hypoxemia, when compared to physiotherapy intervention.[16] The FVC was not improved postoperatively in patients receiving EPAP compared to those receiving incentive spirometry or physiotherapeutic interventions.[30] In constrast, our results show superiority for the variables analyzed after the application of EPAP associated with PPI in comparison to isolated physiotherapeutic intervention. As in this study, other authors[20,29] have also concluded that the application of PEEP should be used as an adjuvant in the routine physiotherapeutic intervention for surgical patients.

Reduced pulmonary function, worsening of gas exchange, and higher rates of pulmonary complications have been associated with the reduction of IMS.[4, 5,9,12] In this study, the values of MIP showed significant reductions from preoperative to 1st PO measurements for the groups studied, and the reestablishment of this variable was found only for the GEP. These results suggest an additional effect by EPAP regarding an earlier reversion of IMS when compared to isolated physiotherapeutic intervention, since significantly higher values were found for MIP on the 1st and 5th PO for the GEP than for the GPI.

The improvement of MIP in the postoperative period was confirmed by Elias et al.,[9] even without training directed towards inspiration muscles, in agreement with our results in that no specific muscle training had been done. This increase can be related to a possible improvement in the mechanics of thoracic-abdominal movement and consequently an increase in the amplitude of respiratory movements,[9] which were not measured in this study.

This study presents some limitations such as the absence of a group with only EPAP application without PPI, which would meet the objective of verifying whether patients who underwent this treatment would present higher pulmonary function values and inspiratory muscle strength, when compared to patients who underwent physiotherapeutic intervention. However, in our study, all patients followed a routine established by the hospital's physiotherapeutic section.

Another important aspect was the limited number of EPAP kits available, which kept the sample size small. While some additional benefits were observed with the use of PEEP in this study, it is necessary to consider the cost/benefit ratio of using this equipment in addition to the proposed physiotherapeutic treatment.

In conclusion, patients who underwent elective cardiac surgery with cardiopulmonary bypass exhibited reductions in postoperative pulmonary function and muscle strength . Physiotherapeutic intervention associated with the application of positive end-expiratory pressure improved the recovery of these patients in comparison to physiotherapeutic intervention alone. However the pulmonary volumes were not completely reestablished until the 5th PO, suggesting the need to continue treatment after the period of hospital convalescence. Due to the small sample size in this study, the performance of new studies to better establish the results obtained in this study is suggested.

RESUMO

Borghi-Silva A, Mendes RG, Costa F de SM, Lorenzo VAP Di, Oliveira CR de, Luzzi S. A influência da pressão positiva expiratória final (PEEP) associada à intervenção fisioterapêutica na fase I da reabilitação cardiovascular. Clinics. 2005;60(6):465-72.

OBJETIVO: Avaliar os efeitos da pressão positiva expiratória final e da intervenção fisioterápica na fase I da reabilitação cardiovascular sobre o comportamento da função pulmonar e da força muscular inspiratória e sobre o pós-operatório de cirurgia cardíaca.

MÉTODO: Estudo prospectivo, randomizado, com 24 pacientes, separados em 2 grupos: GEP (n=8), que realizaram exercícios respiratórios com pressão positiva expiratória nas vias aéreas associados à intervenção fisioterápica; e GFI (n=16), que realizaram somente a intervenção fisioterápica. A função pulmonar foi avaliada pela espirometria no pré e 5º dia pós-operatório; a força muscular inspiratória pela pressão inspiratória máxima no pré, 1º e 5º dias pós-operatório.

RESULTADOS: As variáveis espirométricas mostraram reduções significativas do pré para o 5º dia pós-operatório no GFI, porém no GEP, observou-se redução apenas para capacidade vital ($p<0,05$). Com relação às diferenças entre os tratamentos, foram observados menores valores no GFI para o pico de fluxo no 5° dia pós-operatório. Foram observadas reduções significativas da pressão inspiratória máxima do pré para 1º dia pós-operatório em ambos os grupos. A pressão inspiratória máxima mostrou reduções significativas da situação pré para o 5º pós-operatório somente no GFI (p<0,05).

CONCLUSÕES: Estes dados sugerem que a cirurgia cardíaca produz reduções da força muscular inspiratória, dos volumes e fluxos pulmonares e que a pressão positiva associada à intervenção fisioterápica foi mais eficiente em minimizar essas alterações do que quando a fisioterapia foi realizada de forma isolada. Entretanto, os volumes pulmonares não foram completamente restabelecidos até o 5° dia pós-operatório em ambos os grupos, sendo necessária a continuidade dos tratamentos após a convalescença hospitalar.

PALAVRAS-CHAVE: **Cirurgia Cardíaca. Função Pulmonar. Força Muscular Inspiratória. Fisioterapia. PEEP.**

REFERENCES

1. Timerman A, Cesar LAM. Manual de Cardiologia. São Paulo: Editora Atheneu; 2000.
2. Brasil LA, Mariano JB, Santos FM, Silveira AL, Melo N, Oliveira NG, et al. Revascularização do miocárdio sem circulação extracorpórea: experiência e resultados iniciais. Rev Bras Cir Cardiovasc. 2000;15(1):6-15.
3. Sundt TM, Bailey MS, Moon MR, Mendeloff EN, Huddleston CB, Pasque MK et al. Quality of life after aortic valve replacement at the age of > 80 years. Circulation. 2000;102(19 Suppl 3):III 70-4.
4. Beluda FA, Bernasconi R. Relação entre força muscular respiratória e circulação extracorpórea com complicações pulmonares no pós-operatório de cirurgia cardíaca. RSCESP. 2004;14(5):1-9.
5. Schuller D, Morrow LE. Pulmonary complications after coronary revascularization. Curr Opin Cardiol. 2000;15:309-15.
6. Butler J, Rocker GM, Westaby S. Inflammatory response to cardiopulmonary bypass. Ann Thorac Surg. 1993;55:552-9.
7. Magnusson L, Zemgulis V, Wicky S, Tyden H, Thelin S, Hedenstierna G. Atelectasis is a major cause of hypoxemia and shunt after cardiopulmonary bypass: an experimental study. Anesthesiology. 1997;87:1153-63.
8. Oikkonen M, Karjalainen K, Kahara V, Kuosa R, Schavikin L. Comparison of incentive spirometry and intermittent positive pressure breathing after coronary artery bypass graft. Chest. 1991;99:60-5.
9. Elias DG, Costa D, Oishi J. Efeitos do treinamento muscular inspiratório no pré e pós-operatório de cirurgia cardíaca. Rev Bras Ter Intens. 2000;12(1):9-18.
10. Barbosa RAG, Carmona MJC. Avaliação da função pulmonar em pacientes submetidos à cirurgia cardíaca com circulação extracorpórea. Rev Bras Anestesiol. 2002;52:689-99.
11. Guizilini S, Gomes WJ, Faresin SM, Carvalho ACC, Jaramillo JI, Alves FA, et al. Efeitos do local de inserção do dreno pleural na função pulmonar no pós-operatório de cirurgia de revascularização do miocárdio. Rev Bras Cir Cardiovasc. 2004;19(1): 47-54.
12. Johnson D, Hurst T, Thomson D, Mycyk T, Burbridge B, To T, et al. Respiratory function after cardiac surgery. J Cardiothorac Vasc Anesth. 1996;10:571-7.
13. Westerdahl E, Lindmark B, Bryngelsson I, Tenling A. Pulmonary function 4 months after coronary artery bypass graft surgery. Respir Med. 2003;97:317-22.
14. Kristjansdottir A, Ragnarsdottir M, Hannesson P, et al. Respiratory movements are altered three months and one year following cardiac surgery. Scand Cardiovasc J. 2004;38:98-103.
15. Richter Larsen K, Ingwersen U, Thode S, Jakobsen S. Mask physiotherapy in patients after heart surgery: a controlled study. Intensive Care Med. 1995;21:469-74.
16. Frolund L, Madsen F. Self-administered prophylactic postoperative positive expiratory pressure in thoracic surgery. Acta Anaesthesiol Scand. 1986;30:381-5.
17. Andersen JB, Jespersen W. Demonstration of intersegmental respiratory bronchioles in normal human lungs. Eur J Respir Dis. 1980;61:337-41.
18. Stock MC, Downs JB, Cooper RB, et al. Comparison of continuous positive airway pressure, incentive spirometry, and conservative therapy after cardiac operations. Crit Care Med. 1984;12:969-72.
19. Jenkins SC, Soutar SA, Loukota JM, Johnson LC, Moxham J. Physiotherapy after Coronary artery surgery: are breathing exercises necessary? Thorax. 1989;44:634-9.

20. Campbell T, Fergunson N, McKinlay RGC. The use of a simple self-administered method of positive expiratory pressure (PEP) in chest physiotherapy after abdominal surgery. Physiotherapy. 1986;72:198-200.

21. American Thoracic Society. Pulmonary Rehabilitation. Am J Respir Crit Care Med. 1999;159:1666-82.

22. Knudson RJ, Lebowitz MD, Holberg CJ, Burrows B. Changes in the normal maximal expiratory flow-volume curve with growth and aging. Am Rev Respir Dis. 1983;127:725-34.

23. Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. Am Rev Respir Dis. 1969;99:696-702.

24. Christensen EF, Schultz P, Jensen OV, Egebo K, Engberg M, Gron I, et al. Postoperative pulmonary complications and lung function in high-risk patients: a comparison of three physiotherapy regimens after upper abdominal surgery in general anesthesia. Acta Anaesthesiol Scand. 1991;35:97-104.

25. Campeau L. The Canadian Cardiovascular Society grading of angina pectoris revisited 30 years later. Can J Cardiol. 2002;18:371-9.

26. Senra DF, Iasbech JA, Oliveira SA. Pós-operatório em cirurgia cardíaca de adultos. RSCESP. 1998;8:446-54.

27. Irwin S, Tecklin J. Fisioterapia Cardiopulmonar. 1994. 2nd ed. São Paulo: Manole; 315-324.

28. Craig, DB. Postoperative recovery of pulmonary function. Anaesth Analg. 1981;60:46-51.

29. Ricksten SE, Bengtsson A, Soderberg C, Thorden M, Kvist H. Effects of periodic positive airway pressure by mask on postoperative pulmonary function. Chest. 1986;89:774-81.

30. Stock MC, Downs JB, Gauer PK, Alster JM, Imrey PB. Prevention of postoperative pulmonary complications with CPAP, incentive spirometry, and conservative therapy. Chest. 1985;87:151-7.