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Respiratory muscle training in patients submitted to coronary arterial bypass graft

Treinamento muscular respiratório na revascularização do miocárdio

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Abstract

Objectives: **1) To demonstrate the impaired ventilatory capacity in the postoperative period in patients submitted to coronary artery bypass grafting (CABG). 2) To test the hypothesis that respiratory muscle training (RMT), performed after surgery, may improve the ventilation capacity in this population.**

Methods: **Randomized study, where 38 patients (age: 65 ± 7 years, 29 male) undergoing coronary artery bypass grafting with cardiopulmonary bypass were divided into two groups: 23 patients in the RMT group and 15 in the control group (CO). The RMT group performed conventional physical therapy + RMT; the CO group performed only conventional physiotherapy. They were assessed at three time points (preoperatively, first postoperative day and hospital discharge), variables: maximal inspiratory and expiratory pressures (MIP and MEP), pain, dyspnea (Borg), peak of expiratory flow (PEF), tidal volume and hospital days.**

Results: **The MIP of the RMT group was higher at discharge (90 ± 26 vs. 55 ± 38 cmH2O, *P* = 0.01) and the MEP (99 ± 30 vs. 53 ± 26 cmH2O, *P* = 0, 02). The PEF of the RMT group was higher after hospitalization (237 ± 93 vs. 157 ± 102 fpm, *P* = 0.02). The tidal volume of the groups was also different at discharge (RMT: 0.71 ± 0.21 vs. CO: 0.44 ± 0.12 liters, *P* = 0.00). There were no differences between groups regarding days of hospitalization, dyspnea or pain.**

Conclusions: **There is loss of respiratory muscle strength in patients undergoing coronary artery bypass grafting. The RMT, performed in the postoperative period, was effective in restoring the following parameters: MIP, MEP, PEF and tidal volume in this population.**

Descriptors: **Myocardial revascularization. Respiratory exercises. Treatment outcome.**

Resumo

Objetivos: **1) Evidenciar a perda de capacidade ventilatória no período de pós-operatório, em pacientes submetidos à revascularização do miocárdio. 2) Testar a hipótese de que o treinamento muscular respiratório (TMR), realizado após a cirurgia, pode melhorar a capacidade ventilatória nessa população.**

Métodos: **Estudo randomizado, onde 38 pacientes (idade: 65 ± 7 anos, 29 masculinos), submetidos à revascularização miocárdica com circulação extracorpórea, foram divididos**

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em dois grupos: 23 pacientes no grupo TMR e 15 no grupo controle (CO). O grupo TMR realizou fisioterapia convencional + TMR, o grupo CO realizou apenas fisioterapia convencional. Avaliaram-se, em três momentos (pré-operatório, primeiro dia de pós-operatório e alta hospitalar), as variáveis: pressões inspiratória e expiratória máximas (Pimáx e Pemáx), dor, dispneia (Borg), pico de fluxo expiratório (PFE), volume corrente e dias de internação.

***Resultados:* A Pimáx do grupo TMR foi maior no momento da alta (90 ± 26 vs. 55 ± 38 cmH_2O, *P*=0,01), assim como a Pemáx (99 ± 30 vs. 53 ± 26 cmH_2O, *P*=0,02). O PFE do grupo TMR foi maior após a internação (237 ± 93 vs. 157 ± 102 lpm, *P*=0,02). O volume corrente dos grupos foi também diferente no momento da alta (TMR: 0,71 ± 0,21 vs. CO: 0,44 ± 0,12 litros, *P*=0,00). Não houve diferenças entre os grupos com relação aos dias de internação, dispneia ou dor.**

***Conclusões:* Ocorre perda de força muscular respiratória em pacientes submetidos à revascularização miocárdica. O TMR, realizado no período pós-operatório, foi eficaz em restaurar os seguintes parâmetros: Pimáx, Pemáx, PFE e volume corrente, nessa população.**

***Descritores:* Revascularização miocárdica. Exercícios respiratórios. Resultado de tratamento.**

INTRODUCTION

In recent decades, the procedures related to myocardial revascularization, specifically to peri-operative, have improved considerably, resulting in fewer complications related to it. However, the incidence of pulmonary complications in the postoperative period remained stable. The deleterious effect of cardiac surgery on pulmonary function may result in higher morbidity and mortality rates, longer hospital stay and higher expenditure of physical and financial resources [1,2]. Respiratory dysfunction in cardiac postoperative are usually multifactorial and may be present, possibly because currently the CABG surgeries are performed in more vulnerable patients (high risk), with a higher tendency to limited functional reserve and often associated with older age [1,3].

There are several factors that may compromise the ventilatory capacity in this population. It can be assumed that such patients after CABG, become prone to develop pulmonary complications resulting from intraoperative interventions, such as anesthesia, cardiopulmonary bypass (CPB), thoracotomy or sternotomy, the patient's hemodynamic status, type and duration of surgery, pain and placement of chest tubes, resulting in reduced lung volume and capacity, changes in values of blood oxygenation, and especially the reduction in lung expansion, which facilitates the installation of atelectasis and pneumonia.

Moreover, there is respiratory muscle dysfunction, related to the loss of ability to generate force [4-6]. There have been found significantly lower values of maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) compared with preoperative values in patients after cardiac surgery. These decreases are due to changes in mechanical properties of the lung and chest wall, resulting from various factors described above [7].

Given the context of pulmonary dysfunction associated with cardiac surgery and its possible repercussions, the respiratory physiotherapy has been widely requested, in order to reverse or mitigate this situation, avoiding the development of pulmonary complications. It uses a variety of techniques, for example, it encourages early mobilization after surgery, minimizing the loss of muscle mass and the use of intermittent positive pressure, to improve ventilation [8,9].

Among the various procedures employed by the respiratory physiotherapy in post-CABG patients in general, is the training of respiratory muscle strength that, in such patients, may be helpful in restoring lung function. It may also promote more effectiveness in clearing the airway, through effective cough, and also potentially prevent respiratory muscle fatigue [10].

Based on the foregoing, it is justified to carry out this study, which aims to highlight the loss of strength present in patients undergoing CABG, in the postoperative period. It also intends to show that the performance of respiratory muscle training during the period of postoperative hospital stay, may increase the respiratory capacity of this population, thus, minimizing possible complications and providing scientific evidence that will strengthen the prescription of physiotherapy in intensive care units and cardiology ward.

METHODS

The study consisted of analytical, experimental and randomized research. The latter was approved by the Ethics in Research Committee of the Hospital Santa Marcelina, in compliance with the Declaration of Helsinki, under the registration number 24/08. All the subjects signed the consent form. In order to carry out this work, in the calculation of the sample, considering a confidence level of 95% and a margin of error of 5%, we calculated the sample size in 46 individuals. The sample consisted of adult individuals undergoing CABG surgery with CPB.

Subjects were randomized, and used a table generated by computer program, with the aid of a professional statistician, into two groups: control group (CO), with 23 individuals and respiratory muscle training group (RMT), with 23 individuals. Regarding the cardiac surgery itself, all of them were elective, and patients were operated under general anesthesia, receiving mechanical ventilation with guaranteed volume by respirometry between 6 and 12 ml/kg of body weight, being ventilated with positive end expiratory pressure (PEEP) between 5 and 7 cmH_2O. The CPB time did not exceed 120 minutes in any of the patients. The sample was obtained by adopting the following inclusion criteria: subjects with preserved cognitive understanding to simple instructions, undergoing CABG surgery with CPB, age over 45 years, presence of a mediastinal drain and a chest tube inserted via intercostal.

Patients who did not fit the inclusion criteria or who had complications during surgery such as cardiopulmonary arrest off CPB and the need for implantation of intra-aortic balloon were excluded. We also excluded patients who presented, during their stay in the ICU, ventricular arrhythmias associated with low cardiac output, blood loss above 500 ml or need for reintubation and return to mechanical ventilation. Before the surgery, according to clinical assessments, there were no significant limitations to expiratory flow, which could characterize chronic obstructive pulmonary disease in these patients.

In group C, a total of 23 randomized patients, eight did not complete the treatment protocol, and, among these, two had ventricular arrhythmias associated with low output, two required reintubation during the ICU and four individuals could not have their data collected due to unscheduled hospital discharge in advance, which made impossible data collection during the end of treatment.

Therefore, the 15 remaining subjects, there was only conventional physiotherapy performed, which consisted of bronchial hygiene (vibrocompression composed of four sets of six expiratory cycles, performed with the aid of hands on the surface of the thorax, associated with postural drainage, placing, based on the radiological image, the more affected side of the lung upwards, and this position was maintained for 20 minutes to maximize the drainage of secretions) and tracheal aspiration when necessary (three to five aspirations with the use of probe number 12 or 14, by intubation with a maximum duration of ten seconds for each of aspirations). Both groups received physical therapy in two daily sessions (morning and afternoon) as routine visits to the service. It is noteworthy that none of the patients underwent RMT preoperatively.

The RMT group, totaling 23 individuals, made conventional physiotherapy + RMT with Threshold device - IMT® (Threshold Inspiratory Muscle Trainer, Healthscan Products Inc.). The protocol for RMT was performed as follows: three sets of ten repetitions, once a day for each day of hospitalization after surgery, with a load of 40% of the initial MIP, obtained by analog manometer (Comercial Médica®).

This protocol was adapted from the study of Hulzebos et al. [11] who used loads of 30% of the initial MIP, with a higher number of repetitions (20 minutes of exposure). Our group sought to use a higher workload (40%), with fewer repetitions (three sets of ten repetitions with two minutes between sets), avoiding any muscle strain of the patient, which could happen with the use of the inspiratory resistor device for longer periods, such as those used in the original protocol proposed by Hulzebos et al [11]. This change was also done in order to emphasize the work of intermediate muscle fibers (IIa), aiming to develop muscle strength and increase the resistance component, typical of these fibers (oxidative and white). The group performed the same RMT always in the morning.

The following variables were assessed at three time points (preoperatively, immediate postoperatively and at discharge): maximal inspiratory pressure (MIP) and expiratory (MEP) using an analog manometer, dyspnea (Borg Scale of Dyspnea), pain (Visual Analog Scale of Pain), peak expiratory flow (PEF) using a digital peak flow device (Piko ®) and, finally, tidal volume (TV) using a digital spirometer (Ventronic ®) .

All procedures applied by the same researcher, to assess patients were explainable and trained beforehand by them, using their devices in order to avoid incorrect values in the measurements. The values of MIP, MEP and

PEF were assessed three times at intervals of one minute between each measurement in each of the different moments, being considered for statistical analysis the highest value obtained in each of the parameters. The measurement of MIP was performed from functional residual capacity and the measurement of MEP was performed from total lung capacity of the individual. Measurement of TV was performed by measuring the minute volume of patients registered for a minute, after adjustment of the equipment at the mouth of the research subjects. It was recorded simultaneously the respiratory rate of the subjects. The TV was obtained by dividing the minute volume by the respiratory rate of the individuals. All methodological procedures of data collection were based on previous experiences of our research group [12,13].

The results obtained in the study were expressed as mean and standard deviation of the means. Data normality was assessed based on the *Shapiro-Wilk* test. Comparing the groups regarding quantitative variables of the study, it was used the test for analysis of variance (ANOVA) of two ways, with *post hoc* of *Scheffé* for P values <0.05. In the comparison of anthropometric characteristics it was used the test for analysis of variance of one way, and *post hoc* of *Newman-Keuls* test for P values> 0.05.

RESULTS AND DISCUSSION

With regard to the anthropometric characteristics of the sample, after randomization, the RMT group had a mean age of 62.13 ± 8.10 years, while the CO group had a mean of 67.08 ± 7.11 years, P = 0. 09. The RMT group comprised 23 patients, being 19 males, while the CO group was composed of 15 patients, being six males (P = 0.10). The body mass index in both groups was similar (RMT: 28.08 ± 6.23 vs. CO: 29.10 ± 5.43, P = 0.23).

In accordance with the literature, our study showed a significant reduction in ventilatory capacity in both groups, in the first day after surgery. All ventilatory variables studied (MIP, MEP, TV, PEF) showed the same behavior, which was also observed in the study by Nardi et al. [14], where there was significant reduction (approximately 50%) in almost all studied values (TV, MIP, MEP and PEF) when comparing the preoperative and the first postoperative day. Cardiac surgeries with CPB determine systemic changes that require specific care postoperatively. Among these systemic changes, there are those with pulmonary origin and those originating from several factors, such as CPB time, use of anesthesia, postoperative pain, fear, presence of risk factors, use of intercostal chest drains among others [10,15]. Patients undergoing cardiac surgery develop, in most cases, pulmonary dysfunction, with significant reduction in lung volumes, impairment in the respiratory function, decreased pulmonary compliance and increased respiratory effort [16].

In our study, it was observed the occurrence of major changes in MIP, MEP, TV and PEF in all subjects undergoing surgery and for the measurements of variables, when comparing the values of the preoperative, immediate postoperative and values obtained on the day of discharge, in the group undergoing CABG who did not perform RMT. Different behavior was observed in the RMT group, which showed restoration of ventilatory function at discharge from hospital, returning its parameters to the values initially observed before surgery.

Figure 1A, which illustrates the changes in tidal volume, shows that the values decreased significantly when comparing preoperative and immediate postoperatively in both groups. In the RMT group, the mean TV decreased from 0.77 ± 0.22 to 0.46 ± 0.18 L / min (P = 0.00) and in the CO group, the TV decreased from 0.63 ± 0 , 18 to 0.43 ± 0.16 L / min (P = 0.00), which shows a fall of equal proportions between groups. However, the RMT group had higher values of TV at discharge, compared to the CO group (0.71 ± 0.21 vs. 0.44 ± 0.12 liters), showing a statistically significant difference (P = 0, 00). The recovery observed in tidal volume shows a greater capacity for gas exchange in patients undergoing RMT, which may contribute to better tissue oxygenation accompanied by lower rates of respiratory or metabolic disorders, from the standpoint of acid-base balance in this population.

Figure 1B illustrates the behavior of peak expiratory flow in the three periods studied in both groups. It is observed in both groups, the same pattern as the previous variable. The latter represented by a significant drop in the values of the first day after surgery compared to preoperative values and significant recovery of amounts only at the time of discharge, when considering the RMT group (281.17 ± 93.26 L / min preoperatively, 132.89 ± 87.19 L / min in the first postoperative day and 237.14 ± 93.21 L / min, in the last day of hospitalization). The CO group showed a significant drop in the first days after surgery, while maintaining low values at discharge (238.32 ± 156.51 l / min preoperatively, 134.64 ± 80.20 L / min in the first postoperative day and 157.14 ± 102.29 l / min on the last day of hospitalization). Significant behavioral differences corroborated by a P value = 0.02. It is worth mentioning here that a higher peak expiratory flow may be associated with better ability to cough by part of the patients, which is relevant in order to avoid accumulation of secretions in the airways of the patients [12,17].

As evidenced in Figure 2A, the values of MIP in the CO group showed a decline in the ability of inspiratory force from the preoperative to the first day after surgery; keeping low values at the time of hospital discharge (preoperative: -72.46 ± -34.61 cmH_2O; first postoperative day: -50.01 ± -39.93 cmH_2O; discharge: ± -55.38 -38.06 cmH_2O, P = 0.01). The values of MIP in the RMT group also showed a decline

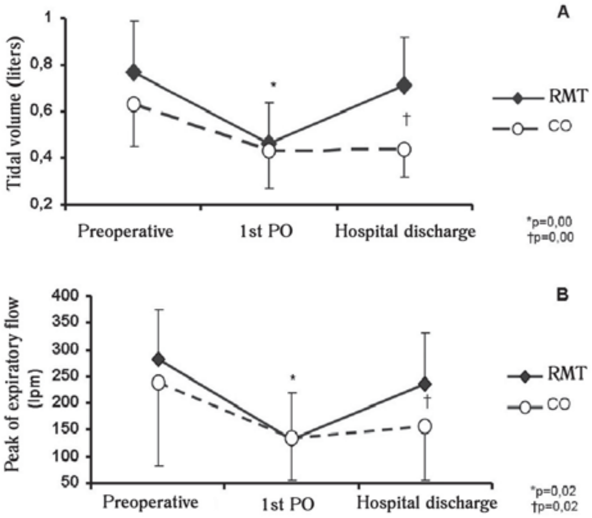

*Fig.1 - (A) Tidal volume (TV) in both groups studied at three time points: preoperative, first postoperative day (POD 1) and at discharge, (B) Peak expiratory flow in both groups studied at three time points: preoperative, first postoperative day (POD 1) and at discharge. CO = control group; RMT group = respiratory muscle training group; lpm = liters per minute * 1 PO vs. Preoperative; † RMT vs. CO*

from preoperative to the first day after surgery and recovered completely the ability of inspiratory force at the time of hospital discharge (preoperative: -91.71 ± -28.24; first postoperative day: -63.35 ± -30.53 cmH_2O; discharge: ± -90.66 -26.08 cmH_2O, $P = 0.01$).

Regarding expiratory pressure (Figure 2B), the CO group maintained the standard reduction in expiratory capacity (preoperative: 73.58 ± 30.60 cmH2O; first day after surgery: 49.14 ± 30.71 cmH_2O; hospital: 53.71 ± 26.71 cmH2O). What draws attention in the analysis of this variable is the changes of values of the RMT group, where the mean 97.65 ± 34.44 cmH_2O in the preoperative period dropped to 72.30 ± 32.38 cmH_2O in the immediate postoperative, increasing to 99.21 ± 30.00 cmH_2O in the last day of hospitalization, showing not only full recovery of the initial value, as well as increase in the mean through respiratory muscle training, also statistically significant ($P = 0.02$).

Similar study by Ferreira et al. [18], which examined the effects of a rehabilitation program of inspiratory muscles in the postoperative period of cardiac surgery, demonstrated an increase in forced vital capacity, maximum voluntary ventilation and the ratio of forced expiratory volume in the first second and forced vital capacity, pointing similarity between the initial and final measurements of maximal inspiratory and expiratory pressures as also observed in our study. Chiappa et al. [19] showed that the respiratory muscle training, carried out for four weeks in patients with heart failure resulted in increased thickness of the diaphragm and even greater capacity of the latter to generate force (72% increase). They also showed that resistance to fatigue on part of the diaphragm increased by about 30% in the group of patients studied. The authors suggest that the accumulation of muscle metabolites in the trained diaphragm would be lower, which would facilitate the latter to maintain its function with higher quality.

Several studies show that pain and dyspnea are major factors when present in patients after cardiac surgery [10,15,16]. Levels of dyspnea in patients submitted to this study did not increase significantly on the first day after surgery ($P = 0.63$), as shown in Figure 3A. On the other hand, the levels of pain increased in both groups on the first day after surgery, decreasing at the time of hospital discharge ($P = 0.00$), as we can analyze as in Figure 3B.

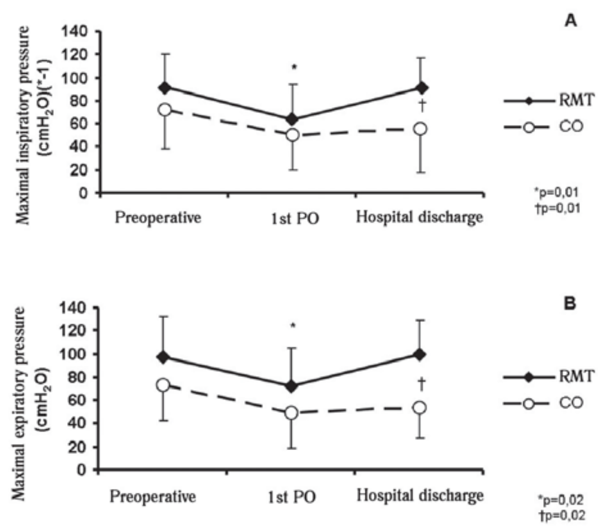

*Fig.2 - (A) Maximal inspiratory pressure (MIP) in both groups at three time points: preoperative, first postoperative day (POD 1) and at discharge, (B) maximal expiratory pressure (MEP) in two groups into three periods: preoperative, first postoperative day (POD 1) and at discharge. CO = control group; RMT group = respiratory muscle training group; cmH_2O = centimeters of water * 1 PO vs. Preoperative; † RMT vs. CO*

The fact that the pain in both groups has behaved similarly at all time points reinforces the benefits of RMT in patients undergoing the latter, whereas, with groups having the same pain perception, we value the intervention performed, excluding the pain factor as limiting for the worst results in the CO group, when compared with the RMT group.

Regarding the duration of CPB, all patients underwent CABG with CPB, with a mean of 60 ± 16 minutes of use thereof, without significant differences between the two groups (RMT: 62 ± 12 versus CO: 57 ± 21 minutes, $P = 0.55$).

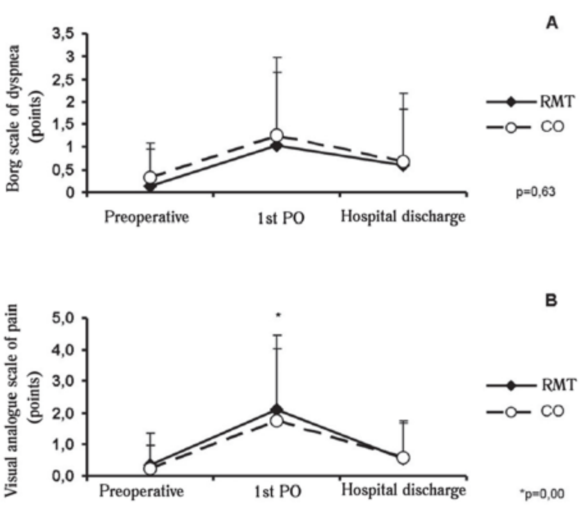

*Fig.3 - (A) of Borg dyspnea scale (in points) applied to both groups at three time points: preoperative, first postoperative day (POD 1) and at discharge, (B) visual analogue scale of pain applied to both groups at three time points: preoperative, first postoperative day (POD 1) and at discharge. CO = control group; RMT = respiratory muscle training group, * 1 PO vs. preoperative*

According to Belud and Bernasconi [20], prolonged cardiopulmonary bypass time was directly related to the incidence of postoperative pulmonary complications. Consistent with this finding, Nardi et al. [14] also showed significant changes related to duration of CPB, with a marked reduction of respiratory capacity in the group undergoing CPB for 120 minutes.

Data obtained on the first day after surgery, in patients of our study confirm the findings cited regarding changes in mechanical ventilation and pulmonary complications, although the CPB time was almost 50% lower than that found in the study of Nardi et al. [14]. A factor to be considered regards to the potential recovery of the respiratory capacity in the subjects of our study, once submitting them to the RMT, since the respiratory dysfunction evidenced retreated in the trained group.

In this study, patients in the RMT group remained hospitalized for 7 ± 2 days and patients in the CO group for 8 ± 2 days and did not indicate at that time, significant differences regarding length of stay ($P = 0.07$). In contrast, a study conducted by Leguisamo et al. [21], the mean length of hospital stay in patients undergoing orientation and physical therapy intervention in the preoperative of cardiac surgery was 14.65 ± 6.61 days in the control group and 11.77 ± 6.26 days in the intervention group. There was significant difference ($P = 0.005$) in length of stay, and the group that performed the physical therapy received early discharge from hospital. The median length of hospital stay was 9.0 days (8.0 to 12.8) in the intervention group and 12 days (9.0 to 19.0) in the control group. The lower incidence of pulmonary complications such as pneumonia and atelectasis, justified such a finding. We believe that with a larger number of patients in our sample, we could also obtain statistical difference in the data concerning the time of admission, favoring a shorter hospital stay for patients undergoing RMT.

Within this context, the respiratory physiotherapy has been increasingly requested, since it uses techniques that can improve respiratory mechanics, lung expansion and bronchial hygiene [22-24]. Considering that in the studied variables we found positive and statistically significant results in this study, in order to demonstrate the efficacy of respiratory therapy associated with respiratory muscle training, to improve ventilation in patients undergoing cardiac surgery, we emphasize the need for prescription of this procedure by cardiac surgeons, seeking a better and speedy recovery of revascularized patients.

This was also verified by means of elegant literature review by Renault et al. [25] in which the authors conclude that cardiac surgery commonly leads to changes in lung function, also reporting the use of respiratory physiotherapy intervention in reversing unfavorable ventilatory signs.

Our study has limitations that must be considered. We were unable to perform the RMT in the preoperative period, since the admission had occurred on the eve of surgery, precluding condition for the performance of RMT before surgery. It is believed that the results would be even more significant with the completion of RMT in the preoperative period. Another point refers to the loss of patients at discharge, in the CO group, which may have interfered in any way in the results obtained in our study.

CONCLUSIONS

In the first days after CABG with cardiopulmonary bypass, there is significant reduction in respiratory muscle strength, as evidenced by the decrease in maximum inspiratory and expiratory pressures, accompanied by a significant worsening of ventilatory function, characterized by decreased tidal volume and peak flow expiratory in the sample. The use of respiratory muscle training is effective for recovery of maximal inspiratory pressure, maximal expiratory pressure, tidal volume and peak expiratory flow. It reinforces the need for assistance in the rehabilitation team in an intensive care environment.

REFERENCES

1. Keenan TD, Abu-Omar Y, Taggart DP. Bypassing the pump: changing practices in coronary artery surgery. Chest. 2005;128(1):363-9.

2. Carvalho ARS, Matsuda LM, Carvalho MSS, Almeida RMS, Schneider DSL. Complicações no pós-operatório de revascularização miocárdica. Ciência, Cuidado & Saúde. 2006;5(1):50-9.

3. Scott BH, Seifert FC, Grimson R, Glass PS. Octogenarians undergoing coronary artery bypass graft surgery: resource utilization, postoperative mortality, and morbidity. J Cardiothorac Vasc Anesth. 2005;19(5):583-8.

4. Barbosa RAG, Carmona MJC. Avaliação da função pulmonar em pacientes submetidos à cirurgia cardíaca com circulação extracorpórea. Rev Bras Anestesiol. 2002;52(6):689-99.

5. Pinheiro BB, Fagundes WV, Ramos MC, Azevedo VLB, Silva JM. Revascularização do miocárdio sem circulação extracorpórea em pacientes multiarteriais, experiência de 250 casos. Rev Bras Cir Cardiovasc. 2002;17(3):242-7.

6. Garcia RCP, Costa D. Treinamento muscular respiratório em pós-operatório de cirurgia cardíaca eletiva. Rev Bras Fisioterap. 2002;6(3):139-46.

7. Westerdahl E, Lindmark B, Almgren SO, Tenling A. Chest physiotherapy after coronary artery bypass graft surgery: a comparison of three different deep breathing techniques. J Rehabil Med. 2001;33(2):79-84.

8. Brasher PA, McClelland KH, Denehy L, Story I. Does removal of deep breathing exercises from a physiotherapy program including pre-operative education and early mobilisation after cardiac surgery alter patient outcomes? Aust J Physiother. 2003;49(3):165-73.

9. Müller AP, Orlandoski M, Macedo R, Constantini C, Guarita-Souza LC. Estudo comparativo entre a pressão intermitente (reanimador de Müller) e contínua no pós-operatório de cirurgia de revascularização do miocárdio. Arq Bras Cardiol. 2006;86(3):232-9.

10. Westerdahl E, Lindmark B, Eriksson T, Friberg O, Hedenstierna G, Tenling A. Deep-breathing exercises reduce atelectasis and improve pulmonary function after coronary artery bypass surgery. Chest. 2005;128(5):3482-8.

11. Hulzebos EH, Helders PJ, Favié NJ, De Bie RA, Brutei de la Riviere A, Van Meeteren NL. Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. JAMA. 2006;296(15):1851-7.

12. Gardenghi G, Santos MN, Galano S, Nascimento CFO, Yamashita PY, Silva RR. As técnicas de empilhamento de ar e de padrão ventilatório fracionado aumentam a capacidade de tosse em pacientes acamados. Arq Bras Cardiol. 2009;93:160.

13. Gardenghi, G, Pinto MIP, Moriya K, Soares F, Mattos DB, Terada V. A técnica de empilhamento de ar aumenta a capacidade de tosse em pacientes acamados. Rev Soc Cardiol Estado de São Paulo. 2008;18:158.

14. Nardi C, Otranto CPM, Paia IM, Forti EMP. Avaliação da força muscular respiratória e função pulmonar em pacientes submetidos à cirurgia cardíaca com circulação extracorpórea. In: 4ª Mostra Acadêmica e Congresso de Pesquisa da UNIMEP [online].; 2006 Out, 24-26; Piracicaba. Anais eletrônicos. Disponível em: URL: http://www.unimep.br/phpg/mostraacademica/anais/4mostra/pdfs/171.pdf

15. van Belle AF, Wesseling GJ, Penn OC, Wouters EF. Postoperative pulmonary function abnormalities after coronary artery bypass surgery. Respir Med. 1992;86(3):195-9.

16. Guizilini S, Gomes WJ, Faresin SM, Bolzan DW, Alves FA, Catani R, et al. Avaliação da função pulmonar em pacientes submetidos à cirurgia de revascularização do miocárdio com e sem utilização de circulação extracorpórea. Rev Bras de Cir Cardiovasc. 2005;20(3):310-6.

17. Panitch HB. Airway clearance in children with neuromuscular weakness. Curr Opin Pediatr. 2006;18(3):277-81.

18. Ferreira PEG, Rodrigues AJ, Évora PRB. Efeitos de um programa de reabilitação da musculatura inspiratória no pós-operatório de cirurgia cardíaca. Arq Bras Cardiol. 2009;92(4):275-82.

19. Chiappa GR, Roseguini BT, Vieira PJ, Alves CN, Tavares A, Winkelmann ER, et al. Inspiratory muscle training improves blood flow to resting and exercising limbs in patients with chronic heart failure. J Am Coll Cardiol. 2008;51(17):1663-71.

20. Beluda FA, Bernasconi R. Relação entre força muscular respiratória e circulação extracorpórea com complicações pulmonares no pós-operatório de cirurgia cardíaca. Rev Soc Cardiol Estado de São Paulo. 2004;14(5):1-7.

21. Leguisamo CP, Kalil RAK, Furlani AP. A efetividade de uma proposta fisioterapêutica pré-operatória para cirurgia de revascularização do miocárdio. Rev Bras Cir Cardiovasc. 2005;20(2):134-41.

22. Westerdahl E, Lindmark B, Eriksson T, Hedenstierna G, Tenling A. The immediate effects of deep breathing exercises on atelectasis and oxygenation after cardiac surgery. Scand Cardiovasc J. 2003;37(6):363-7.

23. Jerre G, Beraldo MA, Silva TJ, Gastaldi A, Kondo C, Leme F, et al. Fisioterapia no paciente sob ventilação mecânica. Rev Bras Terapia Intensiva. 2007;19(3):399-407.

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

25. Renault JA, Costa-Val R, Rossetti MB. Fisioterapia respiratória na disfunção pulmonar pós-cirurgia cardíaca. Rev Bras Cir Cardiovasc. 2008;23(4):562-9.