Original Article

The Effects of Intermittent Positive Pressure and Incentive Spirometry in the Postoperative of Myocardial Revascularization

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Summary

Background: **Pulmonary complications are important causes of morbidity and fatalities among patients subject to cardiac surgery. The respiratory physiotherapy has been aiding in the recovery of these patient ones.**

Objective: **To evaluate the physiotherapeutic effect of intermittent positive pressure breathing (IPPB) and incentive spirometry (IS) in patients submitted to myocardial revascularization surgery.**

Methods: **Forty patients were divided in two groups: one was submitted to IPPB (n=20) and the other to IS (n=20). The patients were evaluated at the preoperative period and 24, 48 and 72 hours postoperatively, with the resources being applied in the postoperative period. The following parameters were analyzed: oxygen saturation (SpO_2), respiratory frequency (RF), minute volume (MV), current volume (CV), maximum inspiratory pressure (Ip_{max}) and maximum expiratory pressure (Ep_{max}).**

Results: **The groups were considered homogeneous regarding the demographic and clinical variables. In the group submitted to IPPB, an increase in SpO_2 was observed 48 (p=0.007) and 72 h (p=0.0001) after surgery, when compared to the IS group. As for the RF, MV and CV variables, there were no statistically significant differences between the groups. The group submitted to IS showed a significant increase in the Ep_{max} 24 (p=0.02) and 48 h (p=0.01) after surgery.**

Conclusion: **Aiming at reversing hypoxemia earlier, IPPB showed to be more efficient when compared to IS; however, IS was more effective in improving respiratory muscle strength. (Arq Bras Cardiol 2007;89(2):94-99)**

Key words: **Physical therapy (speciality); postoperative care; respiratory physical therapy; myocardial revascularization.**

Introduction

The myocardial revascularization surgery has now been performed for more than thirty years[1]; nevertheless, pulmonary complications are important causes of increased morbidity and mortality in patients submitted to this procedure[2].

Pulmonary function alterations identified in patients submitted to myocardial revascularization surgery depend on several factors, such as the preoperative pulmonary function, associated co-morbidities (obesity, smoking, sedentarism, age) type and time of surgery, the necessity or not and duration of extracorporeal circulation (ECC), the intensity of the surgical manipulation and the presence of pleural drainage[3].

Physical therapy is frequently used in the prevention and treatment of postoperative pulmonary complications such as atelectasis, pleural effusion and pneumonia in an attempt to accelerate the process of pulmonary function recovery[4], as the full recovery occurs only 15 days after the surgical procedure[5].

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Some resources can be used to perform the respiratory physical therapy in the postoperative period of heart surgery, such as physical therapy maneuvers, continuous positive airway pressure (CPAP), bilevel positive airway pressure (BIPAP), expiratory positive airway pressure (EPAP), intermittent positive pressure breathing (IPPB) and incentive spirometry (IS), which are safe and easy-to-apply resources that can be applied during the postoperative period. There are technical differences among these resources, as each one has a specific action in the recovery of pulmonary function and respiratory mechanics[6-8].

Therefore, there are questions on which is the best resource for specific postoperative complications of myocardial revascularization surgery.

The aim of the present study is to analyze the physiotherapeutic effect of intermittent positive pressure breathing (IPPB) and incentive spirometry (IS) in patients submitted to myocardial revascularization surgery.

Methods

The study was approved by the Research Ethics Committee of PUCPR, process # 669 and it was sent to Conep. The patients signed a written informed consent form prior to enrollment.

Forty patients were submitted to myocardial revascularization surgery from August 2005 to April 2006, at the Hospital of the *Irmandade da Santa Casa de Misericórdia de Curitiba*. The study was prospective and the patients were randomized by drawing lots, prior to the surgery, and divided into 2 groups: IPPB: 20 patients; IS: 20 patients. (It was not necessary to change patients from the groups due to clinical criteria).

The IPPB group consisted of 40% women and 60% men, and the IS group consisted of 20% women and 80% men (p=ns).

The patients in the IPPB group were submitted to intermittent positive pressure breathing (IPPB) through a Müller Reanimator (MR) manufactured by Engesp™, with a rubber facial mask for ten minutes, followed by a 5-minute interval and a new application for 10 minutes. The IS group was submitted to volume-oriented incentive spirometry, using a Voldyne model 5000™, (Sherwood Medical, USA), for the same time and interval.

During the preoperative period, the patients were submitted to spirometry in a Microlab™ equipment manufactured by Micro Medical Ltda., microlab 3500 model, for the analysis of the predicted values of the following variables: FEV1 (Forced Expiratory Volume in 1 second) and the FEV1/FVC (forced vital capacity) ratio (Tiffeneau index). The patients had to present normal respiratory patterns or mild respiratory dysfunction in order to be enrolled in the study.

The following pre- and postoperative variables were assessed: age, weight, height, body mass index (BMI), time of surgery and of extracorporeal circulation, number and location of drains.

The following postoperative parameters were assessed: oxygen saturation (SpO_2) in ambient air measured by a pulse oxymeter manufactured by Nonin™, model 9500, current volume (CV) (CV = MV (minute volume)/RF (respiratory frequency), measured in a Whigth ventilometer manufactured by Respirameter™, model Ferraris – Mark 8, maximum inspiratory pressure (Ip_{max}) and maximum expiratory pressure (Ep_{max}), which was measured in a Gerar™ equipment. These data were collected 24, 48 and 72 hours after surgery.

At the statistical analysis, the null hypothesis for equal means in the pre- and post-treatment evaluation with IS and of the MR *vs* the alternative hypothesis of different means was tested. Student's *t* test was used for independent samples to compare the two groups defined by the type of resource. When comparing the pre- and post-respiratory treatment evaluation moments, Student's *t* test was used for paired samples. The non-parametric Mann-Whitney test was used to compare the groups regarding the number of bypass grafts. P values < 0.05 were considered statistically significant.

Results

There was no statistically significant difference between the demographic and clinical variables in the pre- and postoperative periods between the two groups studied. Thus, the two groups were considered to be homogeneous and could be compared between them.

Regarding the Tiffeneau index (FEV1/FVC ratio), the patients submitted to IS presented a mean of 81.95±11.41%, and those submitted to IPPB, of 81.80±7.01% (p=0.96). The mean age of the patients in the IS group was 57.10±9.88 years and it was 56.40±8.89 years in the IPPB group (p=0.81). BMI did not present statistical difference, as the patients submitted to IS presented a mean of 26.82±3.12 Kg/cm², and those in the IPPB, presented 28.64±5.12 Kg/cm² (p=0.18). Regarding the time of extracorporeal circulation (ECC), the patients submitted to IS had a mean of 57.50±11.53 minutes, whereas those in the IPPB group had a mean of 54±9.26 minutes (p=0.29). Concerning the number and location of drains, 100% of the patients presented a mediastinal drain. In the IS group, 75% of the patients presented a chest drain, compared to 80% of the patients in the IPPB group (p=ns). Regarding the number of bypass grafts, the mean of patients submitted to IS was 2.90±0.79 bypass grafts/patient and in the IPPB group, 2.80±0.70. Regarding the analysis of oxygen saturation (SpO_2, %), in the patients who were submitted to IS, the mean SpO_2 24 h after the surgery was 88.50% before IS and 89.55% after IS (p=0.20); after 48 h, the variation was 86.10% to 87.15% (p=0.15) and after 72 h there was an increase from 89.90% to 91.15% (p= 0.05). Regarding the patients that were submitted to IPPB, the mean of SpO_2 24 h after the surgery increased from 88.50% to 88.45% (p=0.96); after 48 h, it increased from 89.40% to 92% (p=0.001) and after 72 h, the variation was 93.35% to 94.70% (p=0.05). When the two groups were compared between them, a statistical difference was observed concerning IPPB after 48 h (p=0.007) and after 72 hours (p=0.001) (Fig. 1).

The analysis of the respiratory frequency (RF) of the patients submitted to IS showed no statistical difference in the three periods analyzed. In the patients submitted to IPPB, the mean RF 24 h after the surgery varied from 23.75 i/min to 20.30 i/min (p=0.005). When the two groups were compared, no statistical difference was observed.

Regarding the minute volume (MV) parameter, although a statistical difference was identified in patients submitted to IS 24 h after surgery (11,725.95 to 12,653.50 ml; p=0.03) as well as in the patients that were submitted to IPPB 48 h after surgery (13,145 to 14,034 ml; p= 0.02), no significant

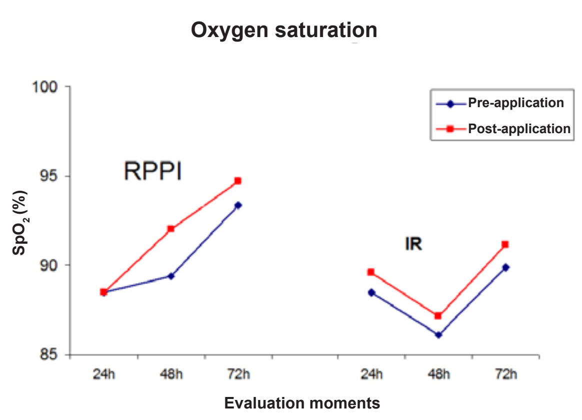

Fig. 1 - Oxygen saturation (SpO_2%).

differences, either intra- or inter-groups, were identified in any of the remaining periods (Fig. 2). Regarding the assessment of the current volume (CV) parameter, no statistically significant difference was observed in either the IS group or the IPPB group, as well as in the comparison between them.

The Ip_{max} of patients submitted to IS did not undergo significant alterations in the three assessed periods; however, in the IPPB group, a significant increase in this parameter was identified 48 h after surgery, as its value varied from 34 to 38 cmH_2O ($p=0.03$). When the two groups were compared between them, a statistically significant difference was observed with an increase of Ip_{max} 48 h before the resource was applied ($p=0.04$) and 72 h after the surgery, in the group that was submitted to IS (Table 1).

Regarding the Ep_{max}, no significant difference was observed either in the IS group or the IPPB group separately; however, there was an increase in this parameter in the IS group, when compared to the IPPB group, 24 h ($p=0.02$) and 48 h ($p=0.01$) after the resources were applied, and 48 h ($p=0.004$) before the resources were applied (Table 2; Fig. 3).

Discussion

The knowledge of the physiopathological bases of the development of postoperative pulmonary dysfunction is essential to assess the pulmonary complications that occur after surgical interventions and to define therapeutic approaches[9].

The pulmonary complications that take place in the postoperative period of myocardial revascularization surgery, such as sternotomy, anesthesia, presence of chest drains that alter the function of respiratory mechanics with a decrease in residual volume (RV), total pulmonary capacity, vital capacity (VC) and functional residual capacity (FRC), which lead to atelectasis, alter the ventilation/perfusion ratio and initiate the process of $PaCO_2$, PaO_2 alterations[10].

The knowledge of pulmonary diseases or dysfunctions that can accompany the previous history of the patients, such as chronic obstructive pulmonary disease (COPD), smoking, obesity and age, is an important factor to be observed, as the success of pulmonary recovery in the postoperative period also depends on the preoperative assessment and status, which evaluate the surgical risk the patient will be submitted to[3].

At the preoperative analysis of the present study the groups were considered homogenous, as there was no statistical difference regarding the following variables: Tiffenau index (FEV1/FVC), forced expiratory volume in the first second (FEV1), age, weight, height, BMI; time of extracorporeal circulation (ECC), number and location of drains in the mediastinum and thorax, number of bypass grafts and analgesic agents in the postoperative period. Hence, it was possible to evaluate the groups between them.

Regarding the oxygen saturation (SpO_2, %), hypoxemia was observed at the three moments of the evaluation, before as well as after the resources were applied. Hypoxemia is a systemic complication that can cause conditions such as metabolic acidosis, mesenteric ischemia and renal failure[11]. According to Malbowisson, hypoxemia can be triggered by the ECC, which causes alveolar interstitial edema and, consequently, pulmonary atelectasis, generally located in pulmonary bases[12].

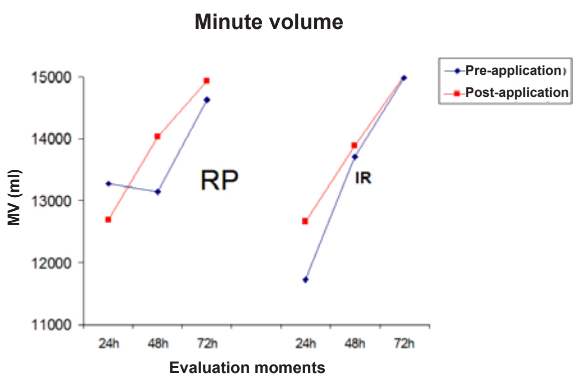

Fig. 2 - Minute volume (ml).

Table 1 – Comparison between the IS and IPPB groups (cmH_2O) regarding the Ip_{max} parameter (cmH_2O)

Variables	Mean	SD	p
Ip_{max} – 24h before IS	39.50	27.09	0.27
Ip_{max} – 24h before MR	31	20.75	
Ip_{max} – 24h after IS	43	27.79	0.16
Ip_{max} – 24h after MR	32.25	20.16	
Ip_{max} – 48h before IS	51.25	27.81	0.04
Ip_{max} – 48h before MR	34	23.49	
Ip_{max} – 48h after IS	55.12	31.39	0.06
Ip_{max} – 48h after MR	38	24.68	
Ip_{max} – 72h before IS	60.25	27.74	0.13
Ip_{max} – 72h before MR	46.75	28.57	
Ip_{max} – 72h after IS	63.90	29.37	0.04
Ip_{max} – 72h after MR	46.50	24.61	

Table 2 – Comparison between the IS and IPPB groups (cmH_2O) regarding the Ep_{max} parameter

Variables	Mean	SD	p
Ep_{max} – 24h before IS	46.50	30.78	0.07
Ep_{max} – 24h before MR	31.75	19.08	
Ep_{max} – 24h after IS	48.25	30.49	0.02
Ep_{max} – 24h after MR	30.75	14.07	
Ep_{max} – 48h before IS	57.25	30.50	0.004
Ep_{max} – 48h before MR	33.25	15.92	
Ep_{max} – 48h after IS	57.75	29.58	0.01
Ep_{max} – 48h after MR	38	13.61	
Ep_{max} – 72h before IS	62.25	26.88	0.09
Ep_{max} – 72h before MR	49.50	19.32	
Ep_{max} – 72h after IS	64.25	26.02	0.07
Ep_{max} – 72h after MR	51.50	17.48	

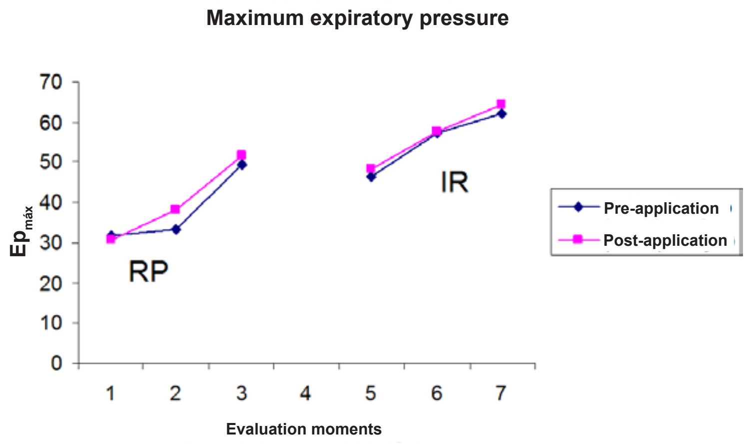

Fig. 3 - *Maximum expiratory pressure (cmH_2O).*

In the present study, a significant increase in SpO_2 was observed when the two groups were compared, with an improvement observed in the group submitted to IPPB 48 and 72 h after surgery. When the analysis of the groups was carried out separately, the IPPB group achieved significant improvement of the SpO_2 48 hrs after surgery. The trend to improvement of SpO_2 in the IPPB group in relation to the IS group may be justified by the fact that IPPB is a passive pulmonary expansion process that does not need an active respiratory work, which can lead to pain increase at the initial moment of recovery from surgery, restricting the respiratory expansion and altering the V/Q ratio.

Concerning the values obtained for SpO_2 at rest, i.e., before the resources were applied, it was observed that in the group submitted to IPPB, hypoxemia was reverted 72 h after surgery, whereas the IS group maintained levels below the normal range. Therefore, it can observed that the O_2 offer generated by the IPPB was more effective than the load imposed by IS for pulmonary expansion. Consequently, it was observed that up to 72 h postoperatively, the O_2 offer through pressure-assisted therapy must be appreciated, instead of increasing O_2 consumption in order to attain muscular strength gain. As a result, the balance between O_2 offer and consumption presented a better equilibrium in the group submitted to IPPB.

Regarding the group submitted to incentive spirometry (IS), the maintenance of hypoxemia within the first postoperative days was due to the difficulty of achieving pulmonary expansion caused by restrictive factors such as pain and the presence of chest drains.

According to West, there is a correlation between the minute volume (MV), current volume (CV) and respiratory frequency (RF). During the postoperative period of heart surgery, the minute volume values can remain within the reference range, although on account of a low CV and high RF, which can lead the patient to respiratory muscle fatigue, oxygen insaturation and even respiratory failure, in some cases[13].

When analyzing the MV, CV and RF parameters, there was no significant difference between the groups, i.e., both the IPPB-stimulated pulmonary expansion, which is a passive mechanism, and the use of IS, which is an active mechanism, attained similar effects in the postoperative period. The MV is the product of the calculation of the CV multiplied by the RF. The use of IPPB and IS improved the CV. This can be justified in the isolated evaluation of each group. The MV increased significantly 24 h after the use of the IS and 48 h after the use of the IPPB. The CV did not achieve significant values either when the groups were compared between them or in the isolated evaluation; however, its mean was higher after the resources were applied.

According to Bott, the therapeutic indication of IPPB within the first hours of the postoperative period re-establishes the pulmonary volumes and capacity earlier. The author also emphasizes that respiratory complications are frequent in the postoperative period of heart surgery and that a decrease in the CV within the first hours is a very common finding, which brings severe systemic consequences caused by cell hypoxemia[14].

Regarding the RF values, a decrease in this parameter was observed at the isolated analysis per group, 24 h after the IPPB was applied. This fact can be justified due to a better synchronization of the inspiratory time during the IPPB, which decreases the respiratory effort. Subjectively, it was also observed that this effort was lower due to the positive pressure exercised by the IPPB. It is known that the lower the effort, the lower the energy expenditure and oxygen consumption by the respiratory muscles. The decrease in the respiratory work improves the energy conversion by the aerobic metabolism in the muscular fibers, especially of heavy-chain fibers, slow-contracting type I fibers present in 50% of the diaphragm fibers in adults[15].

The non-invasive positive pressure ventilation (NIPPV) is an efficient method of passive ventilatory support used to reduce ventilatory work when trying to regain normal pulmonary function, which can prevent respiratory muscle fatigue. The incentive spirometer consists in the increase of the inspiratory effort aiming at improving the distribution of the pulmonary volume, allowing uniform ventilation during the start of inspiration. However, it increases the transpulmonary gradient and alters the respiratory work[16-17].

The peak of postoperative diaphragm dysfunction, with a decrease in its strength, occurs between 2 and 8 h postoperatively, with a return to pre-operative values occurring within 2 weeks, approximately. These alterations occur in response to the surgical procedure and can progress to respiratory complications when they modify the initially predicted course for postoperative recovery. The complications are related to the decrease of the contractile capacity of the diaphragm, directly represented by Ip_{max} and Ep_{max} decrease[18-19]. Regarding the Ip_{max} results obtained in the present study, there was a significant increase in the group submitted to IS when compared to the group submitted to IPPB, 48 and 72 h postoperatively. In the group submitted to IPPB, there was a significant improvement in the inspiratory respiratory muscular function 48 h postoperatively. These results might have been identified due to the removal of thoracic drains carried out around 36 h after the surgery, as the patients present better respiratory muscle contraction in the absence of the drain, which causes pain. Regarding the Ep_{max}, it showed a significant increase in the group submitted to IS when compared to the IPPB group, 24 and 48 h after the resource was applied.

The increase in Ip_{max} and Ep_{max} can be justified in the group submitted to IS as a consequence of the work generated by the resource. This resource results in a higher recruitment of motor units and consequently generates higher muscular strength.

The Ep_{max} increase can be attributed to the increased transversal distension of the respiratory muscle generated by the resisted work during inspiration, as the expiration is a passive process of elastic retraction[20].

The small intergroup improvement regarding Ip_{max} can be attributed to the homogeneity of the groups, as the load tolerated by the individual during exercise is that allowed by each one's individuality during a maximum inspiration, according to height, weight and ventilation-dependent pain. The respiratory muscle strength directly increases with the patient's clinical improvement in the postoperative period, probably due to the pain decrease as a consequence of the removal of drains and the improvement of the elastic components of the thorax through the healing process. After the drain removal, the patient improves the degree of mobility and attains a better posture, consequently decreasing the degree of respiratory muscle weakness and improving its mechanism of action[21].

This fact justifies the improvement of Ip_{max} only after 48 h postoperatively in the IPPB group, as the thoracic expansion is assisted, differently from the IS group, where the work is active. The intergroup improvement identified in the IPPB group can be related to the decrease in the ventilation-dependent pain, allowing better transthoracic pressure.

The better thoracic mobility related to IPPB, caused by the increase in the respiratory capacity allows the diaphragm better amplitude of incursion, which can condition the high-oxidative red fibers, which are fatigue-resistant, to generate higher intrathoracic pressure, resulting in an increase of Ip_{max}.

It is noteworthy the fact that neither of these resources, the IS as well as the IPPB, is used in respiratory muscle training, but in respiratory physiotherapy as pulmonary re-expansion resources. There are some questions regarding the form of use and the treatment principle between them. An individualized use of each resource is suggested for the specific clinical situations presented by the patients.

There is a functional difference between intermittent positive pressure breathing (IPPB) and incentive spirometry (IS). IPPB is a pulmonary expansion technique that injects pressurized air into the airways. The IS is a device to perform respiratory exercises that provides visual stimulation to patients of the inspired volume during an active inspiration, improving respiratory capacity[8,17].

Conclusion

Aiming at reversing hypoxemia earlier, within the first 72 h after the myocardial revascularization surgery, the IPPB was more efficient in comparison to the IS. However, it is suggested that IS was the most effective in improving respiratory muscle strength.

Study limitations - The left ventricular ejection fraction, either pre- or postoperative, was not evaluated, as well as whole blood count and systemic postoperative complications such as heart failure, kidney failure, metabolic and hydroelectrolytic disorders, as they were not part of the study aim and follow-up consisted of only 72 hours.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

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References

1. Favarolo RG. Surgical treatment of coronary arteriosclerosis by the saphenous vein graft technique: critical analysis. Am J Cardiol. 1971; 28 (4): 493-5.

2. 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.

3. Higgins TL, Estafanous FG, Loop FD, Beck GJ, Blum JM, Paranandi L. Stratification of morbidity and mortality outcome by preoperative risk factors coronary artery bypass patients. JAMA. 1992; 267: 2344-8.

4. Loeckinger A, Kleinsasser A, Lindner KH, Margreiter J, Keller C, Hoermann C. Continuous positive airway pressure at 10 cmH_2O during cardiopulmonary bypass improves postoperative gas exchange. Anesth Analg. 2000; 91: 522-7.

5. Wolf G, Brunner JX, Gradel E. Gas exchange during mechanical ventilation

and spontaneous breathing: intermittent mandatory ventilation after open heart surgery. Chest. 1986; 90: 11-7.

6. Westerdahl E, Lindmark B, Almgren SO, Teling 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.

7. Castellana FB, Malbouisson MS, Carmona MJC. Comparação entre ventilação controlada a volume e a pressão no tratamento da hipoxemia no período pós-operatório de cirurgia de revascularização do miocárdio. Rev Bras Anestesiol. 2003; 53 (4): 440-8.

8. Muller AP, Olandoski M, Macedo R, Costantini C, Guarita-Souza LC. Comparative study between intermittent (Muller Reanimator) and continuous positive airway pressure in the postoperative period of coronary artery bypass grafting. Arq Bras Cardiol. 2006; 86 (3): 232-9.

9. Tisi GM. Preoperative evaluation of pulmonary function. Validity, indications, and benefits. Am Rev Respir Dis. 1979; 119 (2): 293-310.

10. Asimakopoulos G, Smith PI, Ratnatunga CP. Lung injury and acute respiratory distress syndrome after cardiopulmonary bypass. Ann Thorac Surg. 1999; 68: 1107-15.

11. Magnusson L, Zemgulis V, Wicky S, Tyden H, Thelin S, Hedenstierna G. Atelectasis is a mayor cause of hypoxemia and shunt after cardiopulmonary bypass. Anesthesiology. 1997; 87: 1153-63.

12. Malbouisson LM, Busch CJ, Puybasset L, Lu Q, Cluzel P, Rouby JJ. Role of the heart in the loss of aeration characterizing lower lobes in acute respiratory distress syndrome. CT Scan ARDS Study Group. Am J Respir Crit Care Med. 2000; 161 (6): 2005-12.

13. West JB. Fisiologia respiratória moderna. 3ª ed. São Paulo: Manole; 1990. p. 11-20.

14. Bott J, Keilty SE, Noonel L. Intermittent positive pressure breathing a dying art? Physioterapy. 1992; 78: 656-60.

15. Johnson PH, Cowley AJ, Kinnear WJ. Evaluation of the threshold trainer for inspiratory muscle endurance training: comparison with the weighted plunger method. Eur Respir J. 1996; 9: 2681-4.

16. Ayres SM, Kozan RL, Lukas DS. The effects of intermittent positive pressure breathing on intrathoracic pressure, pulmonary mechanics and the work of breathing. Am Rev Respir Dis. 1963; 80: 370-9.

17. Overend TJ, Anderson CM, Lucy SD, Bhatia C, Jonsson BI, Timmermans C. The Effect of incentive spirometry on postoperative pulmonary complications: a systematic review. Chest. 2001; 120: 971-8.

18. Siafakas NM. Mitrouska I, Bouros D, Georgopoulous D. Surgery and the respiratory muscles. Thorax. 1999; 54 (5): 458-65.

19. Chandler KW, Rozas CJ, Kory RC, Goldman AL. Bilateral diaphragmatic paralysis complicating local cardiac hypothermia during open heart surgery. Am J Med. 1984; 77: 243-9.

20. Shapira N, Zabatino SM, Ahmed S, Murphy DM, Sillivan D, Lemole GM. Determinants of pulmonary function in patients undergoing coronary bypass operations. Ann Thorac Surg. 1990; 50: 268-73.

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