Three physiotherapy protocols: Effects on pulmonary volumes after cardiac surgery*, **

Três protocolos fisioterapêuticos: Efeitos sobre os volumes pulmonares após cirurgia cardíaca

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Abstract

Objective: To evaluate inspiratory volume in patients undergoing cardiac surgery and to determine the effects that incentive spirometry (IS) and the breath stacking (BS) technique have on the recovery of FVC in such patients. **Methods:** A prospective, controlled, randomized clinical trial involving 35 patients undergoing cardiac surgery at the *Hospital de Força Aérea do Galeão* (HFAG, Galeão Air Force Hospital), in the city of Rio de Janeiro, Brazil. The patients, all of whom performed mobilization and cough procedures, were randomly divided into three groups: exercise control (EC), performing only the abovementioned procedures; IS, performing the abovementioned procedures and instructed to take long breaths using an incentive spirometer; and BS, performing the abovementioned procedures, together with successive inspiratory efforts using a facial mask coupled to a unidirectional valve. Forced spirometry was carried out in the preoperative period and on postoperative days 1 to 5. During the maneuvers, inspiratory volume was measured in the IS and BS groups. **Results:** On postoperative day 1, FVC significantly decreased in all groups (EC: 87.1 vs. 32.0%; IS: 75.3 vs. 29.5%; and BS: 81.9 vs. 33.2%; $p < 0.001$ for all), as did inspiratory volume in the IS and BS groups (2.29 vs. 0.82 L; and 2.56 vs. 1.34 L, respectively; $p < 0.001$ for both). Between postoperative days 1 and 5, FVC partially normalized in all groups (EC: 32.0 vs. 51.3%; IS: 29.5 vs. 46.7%; and BS: 33.3 vs. 54.3%; $p < 0.001$ for all). During the postoperative period, inspiratory volume was significantly higher in the BS group than in the IS group. **Conclusions:** The three protocols were equivalent concerning the recovery of FVC on the first five postoperative days. When compared with IS, the BS technique promoted higher inspiratory volumes in this sample of postoperative cardiac patients. (ClinicalTrials.gov Identifier:NCT01074957 [http://www.clinicaltrials.gov/])

Keywords: Postoperative complications; Thoracic surgery; Physical therapy modalities.

Resumo

Objetivo: Avaliar o volume inspiratório e os efeitos da espirometria de incentivo (EI) e da técnica *breath stacking* (BS) sobre a CVF em pacientes submetidos a cirurgia cardíaca. **Métodos:** Estudo prospectivo controlado e randomizado com 35 pacientes submetidos a cirurgia cardíaca no Hospital de Força Aérea do Galeão, Rio de Janeiro (RJ). Todos os pacientes realizaram procedimentos de mobilização e tosse e foram randomicamente alocados em três grupos: grupo exercício controle (EC), que realizou somente esses procedimentos; grupo EI, que realizou inspirações profundas utilizando um espirômetro de incentivo; e grupo BS, que realizou esforços inspiratórios sucessivos utilizando uma máscara facial acoplada a uma válvula unidirecional. A espirometria forçada foi realizada no período pré-operatório e do primeiro ao quinto dia de pós-operatório. O volume inspiratório foi medido durante as manobras nos grupos EI e BS. **Resultados:** No primeiro dia de pós-operatório, a CVF diminuiu significativamente em todos os grupos (EC: 87,1 vs. 32,0%; EI: 75,3 vs. 29,5%; e BS: 81,9 vs. 33,2%; $p < 0.001$ para todos) assim como o volume inspiratório nos grupos EI e BS (EI: 2,29 vs. 0,82 L; e BS: 2,56 vs. 1,34 L, $p < 0.001$ para ambos). Do primeiro ao quinto dia de pós-operatório, a CVF apresentou recuperação parcial independentemente do protocolo (EC: 32,0 vs. 51,3%; EI: 29,5 vs. 46,7%; e BS: 33,3 vs. 54,3%; $p < 0.001$ para todos). Durante o período pós-operatório avaliado, o volume inspiratório foi significativamente maior no grupo BS do que no EI. **Conclusões:** Os protocolos foram equivalentes no que se refere à recuperação da CVF nos primeiros cinco dias de pós-operatório. Quando comparada à EI, a técnica BS promoveu maiores volumes inspiratórios nesta amostra de pacientes submetidos à cirurgia cardíaca. (ClinicalTrials.gov Identifier:NCT01074957 [http://www.clinicaltrials.gov/])

Descritores: Complicações pós-operatórias; Cirurgia torácica; Modalidades de fisioterapia.

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Introduction

Postoperative pulmonary complications in patients undergoing cardiac surgery represent a significant clinical problem, with a negative impact in morbidity, mortality, length of hospital stay, and health care costs.[1] Lung injury after cardiac surgery includes functional, physiological, biochemical, and histological impairment.[2] Respiratory dysfunction is caused by various factors, such as associated comorbidities, preoperative pulmonary function, and duration of extracorporeal circulation, as well as the type and duration of the surgical procedure.[3,4] In addition, general anesthesia has been shown to reduce functional residual capacity by approximately 20%, and patients undergoing mammary artery grafts have been shown to have a higher risk of pleural effusion and subsequent pulmonary problems.[3]

Physiotherapy has been widely used as a means of improving postoperative pulmonary function.[4] However, it has been questioned whether routine physiotherapy interventions should be undertaken. The physiotherapy techniques most commonly used during the postoperative period include deep breathing exercises, early ambulation, positioning, huffing, and coughing.[3] It has been suggested that postoperative atelectasis can be prevented or treated by spontaneous deep breathing exercises aiming at improving inspiratory capacity and lung compliance.[5] Deep breathing exercises have been shown to improve tidal volume, basal ventilation, and diaphragmatic displacement, facilitating the clearance of secretions.[3] Incentive spirometry (IS), which has been extensively used during the postoperative period, consists of spontaneous deep breathing through a device that provides visual feedback to maintain maximum inflation. However, dyspnea, respiratory muscle weakness, and pain can all impede the performance of IS.[6] In 1990, one group of authors reported that postoperative patients were able to inhale greater volumes and maintain inspiration for a long period of time using a one-way valve device to promote the summation of successive inspiratory volumes while expiration was avoided. This technique is known as breath stacking (BS). The authors stated that this technique could be more effective than is IS in preventing atelectasis and improving gas exchange during the postoperative period.[6] To our knowledge, there have been no studies comparing conventional therapy and BS in terms of their effects on the pulmonary function of postoperative cardiac patients. The objective of the present study was to evaluate inspiratory volume in patients undergoing cardiac surgery and to determine the effects that IS and BS have on the recovery of FVC in such patients.

Methods

This was a prospective, controlled, randomized clinical trial involving patients undergoing cardiac surgery at the *Hospital de Força Aérea do Galeão* (HFAG, Galeão Air Force Hospital), located in the city of Rio de Janeiro, Brazil. The study protocol was approved by Research Ethics Committee of the *Centro Universitário Augusto Mota* (Augusto Mota University Center; protocol 15/2007) and was in accordance with the Helsinki declaration. All participants gave written informed consent. All of the patients who were scheduled for cardiac surgery at the HFAG between November of 2007 and February of 2009 were eligible to participate in the study.

We excluded patients who presented with any of the following: no preoperative tests; cognitive impairment that prevented the performance of IS; and intolerance of the mask employed in the performance of the BS. During the postoperative period, we excluded patients with the following: hemodynamic complications (arrhythmia, intraoperative myocardial infarction, major blood loss [defined as a loss of ≥ 20% of total blood volume],[7] mean arterial pressure < 70 mmHg, and reduced cardiac output requiring the use of an intra-aortic balloon pump or vasoactive drugs); intubation for more than 72 h after admission to the ICU; or the need for reintubation. Data related to patients who died were also excluded from the analysis. In all cases, the surgical procedure was median sternotomy, and the postoperative routine, which included optimal treatment for pain control, did not vary. A verbal pain score was obtained with a visual analog scale,[8] and, for all patients, physiotherapy was initiated on postoperative day 1, following extubation.

Demographic data, clinical history, and preoperative risk factors were recorded. During the preoperative period, all of the patients were informed of the importance of early mobilization and removal of excessive bronchial secretion. The patients were taught the following techniques: huffing (forced expiration with the glottis

open); supported cough (with the hands of the patient placed on the sternotomy incision); mobilization (including active limb exercises); sitting (out of bed); and ambulation (initiated on postoperative day 3 if the patient was extubated by postoperative day 2). All of the patients performed the mobilization protocol and received cough orientation as described above. The patients were then randomly allocated into three groups: those in the exercise control (EC) group performed only the procedures described above; those in the IS group performed all of the procedures described above and were instructed to take long, slow, deep breaths using an incentive spirometer (Voldyne 5000™; Sherwood Medical, St. Louis, MO, USA), from functional residual capacity up to total lung capacity, in accordance with current recommendations(9); and those in the BS group performed the EC group procedures plus the inspiratory efforts, using a facial mask coupled to a unidirectional valve.[6] Since the mask was set to allow only inspiration (the expiratory branch was occluded), the patient performed the maneuver by means of successive inspiratory efforts, for a period of 20 s. Subsequently, the expiratory branch was opened, allowing exhalation. These three types of physiotherapy were applied twice a day for five days, each session consisting of three series of five maneuvers.

For safety purposes, a pulse oximeter (Model 2500A; Nonin Medical Inc., Plymouth, MN, USA) was used in order to monitor HR and SpO_2 throughout the interventions. Mean arterial pressure was recorded prior to and after the procedures. Oxygen therapy was not possible during the procedures, because neither device was designed for that purpose. Therefore, if SpO_2 dropped to < 90%, the intervention was interrupted and oxygen therapy recommenced.[9,10]

All of the procedures were performed under the supervision of a member of the hospital physical therapy staff participating in the study. Forced spirometry was carried out in the preoperative period and from postoperative days 1 to 5, with a Pony Fx® spirometer (Cosmed, Rome, Italy). The spirometric parameters were interpreted on the basis of the equations devised by Pereira et al.[11] A Wright spirometer (British Oxygen Company, London, UK) was attached to the incentive spirometer and to the BS mask, allowing the inspiratory volume to be measured during the procedures.[12] Postoperative risk was evaluated with the Torrington-Henderson scale,[13,14] based on clinical and functional data.

The statistical analysis was performed with SigmaStat software, version 3.1 (Jandel Scientific, San Rafael, CA, USA). Data are presented as means and standard errors of the mean. All of the data presented normal distribution (Kolmogorov-Smirnov test with Lilliefors correction) and homogeneous variances (Levene median test). Among the three groups, FVC values were compared with ANOVA, followed by Tukey's test when multiple comparisons were required. To compare inspiratory volumes between the IS and BS groups, we used Student's t-test. The level of significance was set at 5%.

Results

Our initial sample consisted of 48 patients evaluated in the preoperative period. Of those 48, 13 were excluded (2 dropped out; 2 had myocardial infarction; 3 presented with arrhythmia; 1 was reintubated; 3 had major blood losses; 1 died; and 1 presented with hypotension). Therefore, 35 patients completed the study (11 in the EC group, 12 in the IS group, and 12 in the BS group). All 35 patients were extubated on the day of surgery. There were no statistically significant differences among the three groups in terms of the demographic and functional variables in the preoperative period (Table 1).

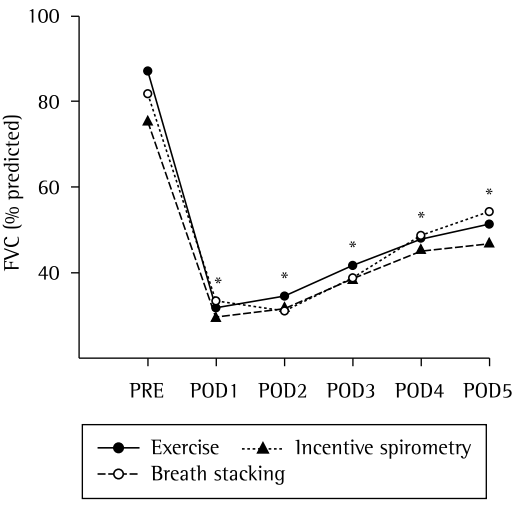

Figure 1 - Mean FVC values (% of predicted) for the exercise control group (n = 11), incentive spirometry group (n = 12) and breath stacking group (n = 12), obtained during the preoperative period (PRE) and on postoperative days (PODs) 1 to 5. *p < 0.001 vs. PRE.

Table 1 - Demographic, functional, and surgical data, by group.[a]

Variable	Exercise control (n = 11)	Incentive spirometry (n = 12)	Breath stacking (n = 12)
Age, years	64 ± 2	60 ± 3	63 ± 3
Male/female, n/n	7/4	10/2	7/5
BMI, kg/m^2	26.3 ± 1.0	25.5 ± 0.9	27.7 ± 1.4
Type of surgery			
CABG/CVS, n/n	10/1	11/1	11/1
Smoker, n	3	3	2
FVC, % of predicted	87.0 ± 4.6	75.0 ± 3.7	82.0 ± 4.7
FEV_1,% of predicted	78.0± 4.9	91.0 ± 4.0	85.0 ± 3.7
FEV_1/FVC, % of predicted	81.0 ± 2.3	79.0 ± 2.6	83.0 ± 2.3
THS, range	2-5	2-4	2-5
Anesthesia time, h	4.28 ± 0.36	5.30 ± 0.56	4.95 ± 0.39
CPB time, min	73.50 ± 11.66	77.22 ± 9.45	64.83 ± 8.83
Duration of intubation, h	11.40 ± 0.45	11.30 ± 0.73	10.33 ± 0.62

BMI: body mass index; CABG: coronary artery bypass; CVS: cardiac valve surgery; THS: Torrington-Henderson scale; and CPB: cardiopulmonary bypass. [a]Values expressed as mean ± SD, except where otherwise noted.

Figure 1 shows the mean FVC values for the three groups at the various time points evaluated. In all three groups, FVC was significantly lower on postoperative day 1 than in the preoperative evaluation (EC: 32.0% vs. 87.1%; $p < 0.001$; IS: 29.5% vs. 75.3%; $p < 0.001$; and BS: 33.3% vs. 81.9%; $p < 0.001$) and partially normalized by postoperative day 5, in comparison with postoperative day 1 (EC: 51.3% vs. 32.0%; $p = 0.001$; IS: 46.7% vs. 29.5%; $p = 0.01$; and BS: 54.3% vs. 33.2%; $p = 0.003$).

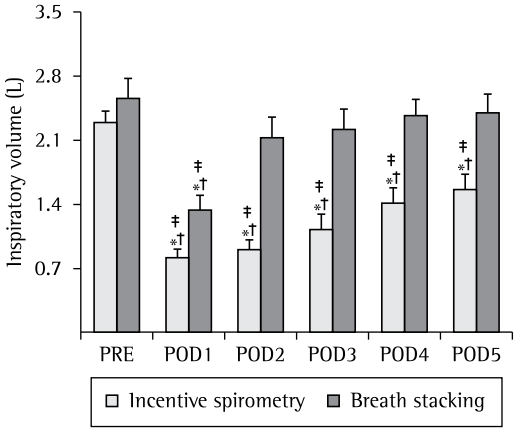

Figure 2 - Mean inspiratory volumes (30 recordings per patient) in the incentive spirometry (IS) and breath stacking (BS) groups, obtained during the preoperative period (PRE) and on postoperative days (PODs) 1 to 5. •p = 0.001 vs. PRE in the IS group. ••p < 0.001 vs. PRE in the BS group. •••p = 0.001; IS group vs. BS group.

Figure 2 shows the mean inspiratory volumes for the two groups at the various time points evaluated. In the IS and BS groups, inspiratory volume was significantly lower on postoperative day 1 than in the preoperative evaluation (0.82 L vs. 2.29 L and 1.34 L vs. 2.56 L, respectively; $p < 0.001$ for both). During the postoperative period, inspiratory volume was significantly higher in the BS group than in the IS group. In the BS group, inspiratory volume normalized completely by postoperative 2.

There were no significant differences among the groups in terms of the mean SpO_2 values during the preoperative period. However, SpO_2 decreased significantly after surgery (on postoperative day 1), recovering partially by postoperative day 5 (EC: 94.2% vs. 97.0%; $p < 0.001$; IS group: 95.1% vs. 97.2%; $p = 0.016$; and BS group: 95.0% vs. 97.7%; $p < 0.001$).

Pain scores ranged from 2 to 5 (median, 4), without significant differences among the groups.

All of the patients were able to perform the techniques, and none experienced any respiratory or adverse hemodynamic effects during the procedures.

Discussion

This study demonstrated that, compared with IS, the BS technique promotes greater mobilization of inspiratory volume in cardiac

surgery patients, with total recovery to the preoperative values by postoperative day 2.

The treatment of postoperative pulmonary complications includes a number of modalities of chest physiotherapy. However, the benefits originated from any method of physiotherapy after cardiac surgery still lack evidence. There are very few studies available to guide the postoperative physiotherapy approach, and there is no consensus in the literature regarding the superiority of one technique over the others.[15]

In the postoperative period, drowsiness, pain, and analgesia can lead to a slow, monotonous, shallow breathing pattern, as well as to recumbent position and decreased mobility, increasing regional hypoventilation.[16] In this situation, the ability to perform deep breathing is important for the effectiveness of cough and to prevent pulmonary complications.[17] It has been shown that spontaneous sighs are diminished during the postoperative period in abdominal surgery patients.[18,19] Therefore, the rationale of physiotherapy is based on pulmonary expansion techniques.

Currently, IS is one of the most common postoperative techniques. However, there is no evidence that IS is more effective than other physiotherapy techniques, and its efficacy has been questioned.[20-22] The ability of a patient to perform IS can be impaired by dyspnea, respiratory muscle weakness, and pain.[6] Therefore, there has been increasing interest in alternative methods of promoting pulmonary expansion. In 1994, one group of authors evaluated the effectiveness of the BS technique in reducing pulmonary shunt fraction and improving gas exchange in cooperative intubated patients after coronary artery bypass.[19] In 2006, another group of authors described the safety of BS with a manual resuscitator bag in the management of critically ill, intubated patients with atelectasis.[23] Despite these promising results, our study is the first clinical trial comparing the effects of BS to the conventional physiotherapy approach in patients undergoing cardiac surgery.

In our study, there was a marked reduction in FVC on postoperative day 1, and the reduction became progressively less pronounced between postoperative days 1 and 5, regardless of the physiotherapy protocol. This result is consistent with those of previous studies, in which respiratory volumes have been shown to decrease markedly after cardiac surgery, with a partial improvement by discharge.[3,24] The lack of any differences among the groups in terms of the postoperative FVC values is likely attributable to the small size of our sample and to the fact that it comprised low-risk patients. Therefore, it is possible that BS would have beneficial effects on lung volumes in high-risk, uncooperative patients who cannot perform IS.

Since the foremost outcome measure of our study was inspiratory volume, inspiratory capacity was recorded only in the BS and IS groups. Although inspiratory capacity in these two groups decreased on postoperative day 1, the inspiratory volume achieved during BS maneuvers was significantly greater than was that achieved during IS. This is consistent with our previous findings when evaluating abdominal surgery patients.[25] As previously described, high inspiratory volume is essential to the effectiveness of cough. Improvements in cough PEF can be achieved when cough is started from the maximal inspiratory volume in normal subjects, in patients with neuromuscular disease,[26] and in postoperative patients.[27] Therefore, in addition to lung reexpansion, it is likely that BS can be used to improve cough PEF in surgical patients.

Respiratory muscle strength can influence spirometric values and the incidence of pulmonary complications in postoperative patients.[28] We did not record maximal respiratory pressures in our study. Nevertheless, if there were significant differences among the groups, this would be reflected by the spirometry results in the preoperative period and in the subsequent postoperative time points.

To ensure the external validity of our study, we applied the expansion techniques in a standardized manner, following current recommendations.[9] Therefore, the duration of the BS maneuvers was greater than was that of IS. According to various authors, the effectiveness of a lung-expansion maneuver might be influenced as much by its duration as by the maximal volume achieved.[6,29,30] Maintaining the lung at high volumes during BS maneuvers could improve collateral ventilation and open previously collapsed areas. In addition, BS maneuvers can be performed even in uncooperative patients.[6]

Prolonged maintenance of high lung volume during BS could lead to potential complications, such as reduced venous return, reduced cardiac output, and increased blood pressure due to the increment of intrathoracic pressure. However, our patients did not present hemodynamic instability during the procedure. According to one group of authors, these complications are unlikely because all pressures are generated by the patient, and the volume achieved is similar to that observed during sighing or coughing.[6]

The present study has some limitations, such as the relatively small number of patients and the specificity of the population. In addition, all of our patients presented with a low risk of pulmonary complications (Table 1), and our results therefore cannot be extrapolated to other surgical populations. Further studies including high-risk patients are needed in order to investigate the effectiveness of BS in clinically relevant outcomes, such as the prevention of pulmonary complications (pneumonia and atelectasis), the recovery of lung volumes, and cough PEF.

In conclusion, the three protocols studied were equivalent regarding the recovery of FVC during the first five postoperative days in this group of patients. The BS technique could be used safely and, when compared with IS, promoted higher inspiratory volumes in low-risk postoperative cardiac patients.

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