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Effects of manual hyperinflation maneuver associated with positive end expiratory pressure in patients within coronary artery bypass grafting

Efeitos da manobra de hiperinsuflação manual associada à pressão positiva expiratória final em pacientes submetidos à cirurgia de revascularização miocárdica

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ABSTRACT

Objective: To verify the effects of manual hyperinflation maneuver associated with positive end expiratory pressure in coronary artery bypass grafting patients.

Methods: This was a randomized trial, conducted from August 2007 to July 2008 in the intensive care unit of the Hospital Luterano (ULBRA). The patients were divided in the groups intervention - with manual hyperinflation plus positive end expiratory pressure - and control. The ventilatory variables were measured before and after the manual hyperinflation. The t Student's test was used for independent and paired samples as well as Fisher's exact test and McNemar's Chi-square test with 0.05 significance level.

Results: Eighteen patients were included. The mean age was 64±11 years and 55.6% were female. The inspired tidal volume was 594±112 ml in the intervention group and 487±51 ml in the control group (p=0.024) and the expired tidal volume was 598±105 ml in the intervention group and 490±58 ml in the control group (p=0.02). The mean pre-maneuver static pulmonary compliance in the intervention group was 41.6±12.1 ml/cmH_2O and post maneuver it was 47.4±16.6 ml/cmH_2O (p=0.03). There was no significant between groups difference in the following variables: oxygen peripheral saturation, oxygen arterial pressure, extubation time and radiological changes.

Conclusion: The results show that the manual hyperinflation associated with positive end expiratory pressure maneuver trends to promote increased lung volumes and static compliance, however these findings require further confirmation.

Keywords: Respiratory therapy; Rehabilitation; Respiration, artificial; Breathing exercises; Physical therapy modalities; Positive-pressure respiration; Myocardial revascularization

INTRODUCTION

Although the countless advances in perioperative care, heart surgery patients have very

frequent pulmonary complications, which represent relevant cause of morbidity and mortality, increasing both hospital stay and costs.[1,2] The frequency of these complications is highly variable, ranging between 6% and 76%, and is related to several predisposing factors, inherent to heart surgery. In addition to pulmonary changes, such as atelectasis, pleural effusion, pneumonia among others, other important complications can also occur such as prolonged mechanical ventilation and neurological disorders.[3-6]

Currently, the physiotherapist is involved in the intensive care unit (ICU) patient's admission, mechanic ventilation installation and ventilatory parameters adjustment. Generally the first treatment is performed after the routine procedures and patient stabilization. During this period, the physiotherapy aims keeping the airways free of bronchial secretions, and the lungs expanded. The conventional physiotherapy effectiveness has been challenged, and looks having no clinical relevance for patients undergoing heart surgery; thus, evidences suggest changes in physiotherapy approaches.[7] For this, it is possible the use of bronchial secretion removal and pulmonary expansion techniques based on judicious evaluation, as manual hyperinflation (MH) and positive end-expiratory pressure (PEEP) therapy.[8-10]

MH is frequently used for ICU patients' assistance by intensivist physicians and physiotherapists aiming to passively inflate the lungs and increase the expiratory peak flow, consequently, improving the compliance, increasing the secretions mobilization and preventing mechanic ventilation-associated pneumonias.[11-14]

PEEP, in turn, has as primary effect for alveolar distensibility maintenance at the end of expiration, preventing the collapse of these gas exchange units, being fundamental for hypoventilation-associated atelectasis.[15,16]

Thus, this trial aimed to verify the effects of manual hyperinflation maneuver associated with PEEP in patients undergoing heart surgery such as elective coronary artery bypass grafting (CABG) in the immediate post-operative period.

METHODS

This was a randomized clinical trial, approved by the Universidade Luterana do Brasil's Ethics Committee, and conducted from August 2007 to July 2008 in the adult ICU of the Hospital Luterano (ULBRA).

Patients undergoing elective CABG under extracorporeal circulation (ECC) were admitted to the hospital at least 24 hours before surgery. Thus, they were invited to take part in the trial, received study information and signed the Informed Consent Form (ICF).

Were excluded patients undergoing reoperation, and those with severe chronic obstructive pulmonary disease (COPD), with airway flow limitation ($FEV_1 \leq$ 30% predicted), with clinical signs of right ventricular failure and acute radiographic changes.

The subjects were randomly assigned, using sealed envelopes cards, to undergo early physiotherapy with manual hyperinflation associated with PEEP, or to the control group.

Returning from the surgery center, the patients were received at the ICU, monitored and positioned in dorsal decubitus. Both groups were equally ventilated according to the unit routine, with controlled pressure and a 8 ml/Kg tidal volume, and initial inspired oxygen fraction (FiO_2) 1.0. This admission procedure took, in average, one hour. All patients had two chest drain tubes (one mediastinal and one pleural).

In the control group, the unit routines for handling immediate post-operative patients were maintained, such as adaptation to mechanic ventilation, strict vital signs control and later laboratory tests collection, among them, arterial gasometry. From clinical and hemodynamic stability, and clearance of circulating anesthetics, the patients proceeded to weaning and extubation. No physiotherapeutic intervention was used.

In the intervention group, after adapted to mechanic ventilation by the unit's physicians and physiotherapists team, the patients received one single 20 minutes session, using as resource the manual hyperinflator and the spring load valve to keep PEEP. The self-inflatable Ambu® bag had 3 liters capacity, and was connected to a 15 L/min oxygen flow. A manometer was connected to the system, in order to maintain fixed pressures. A 35 cmH_2O inspiratory pressure was used, with 10 cmH_2O PEEP. The inhaled and exhaled tidal volume during MH, as well as the hyperinflations frequency, were not measured. This procedure was followed by endotracheal tube and upper airways aspiration. Just after the procedure, arterial gasometry was collected.

The static pulmonary compliance (Cst) was calculated, with the formula:

$$Cst = \frac{\text{tidal volume}}{\text{plateau pressure - PEEP}}$$

For the respiratory mechanics calculation, in addition to the patient being sedated, the ventilation parameters were kept during all measurements to allow comparative interpretation.

Data related to the extubation time were collected from the medical chart, being recorded in minutes, as per the unit routine. Post-operative complications were evaluated, with the chest X-rays analyzed by a radiologist blinded to the study, from the physiotherapeutic intervention until the post-extubation evolution.

Statistical analysis

The quantitative data were described by mean and standard deviation, and the categorical data described

by absolute and relative frequency. The inter-groups difference was represented by their absolute value followed by the 95% confidence interval.

From this information, to check the normal hypothesis for the peripheral oxygen saturation variable, the non-parametrical Kolmogorov-Smirnov test was applied, with a 5% significance level. In order to compare the quantitative inter-groups variables, the t Student for independent samples and pairwise samples tests were applied. For the categorical variables the exact Fisher's and McNemar's Chi-square tests were used.

The data analysis was performed with the software SPSS (Statistical Package for The Social Sciences), version 13.0. The statistical significance level was 5% ($p \leq 0.05$).

RESULTS

Eighteen patients were included between August 2007 and June 2008. The mean age was 64±11 years, being 55.6% females. Table 1 shows the sample characteristics, showing that the control and intervention groups had no relevant differences, with homogeneous population. Table 2 shows a comparison between the groups regarding the outcomes of interest in the post-maneuver phase.

Peripheral oxygen saturation (SpO_2) averaged 99.4±1.0% in the intervention and 98.1±2% in the control groups, respectively. This inter-groups difference (1.3%) (-0.22-2.77%)) was non-significant (p=0.089).

Table 1 – Overall and by groups sample characteristics – pre-maneuver

Variables	Overall (N=18)	Intervention group (N=10)	Control group (N=8)	P value
Age (years)	64.4±11.0	64.5±9.4	64.3±13.4	0.963†
Gender				
Male	8 (44.4)	4 (40.0)	4 (50.0)	1.000††
Female	10 (55.6)	6 (60.0)	4 (50.0)	
Drug use				
Yes*	10 (55.6)	4 (40.0)	6 (75.0)	0.188††
No	8 (44.4)	6 (60.0)	2 (25.0)	
Preoperative X-ray				
With changes**	13 (72.2)	7 (70.0)	6 (75.0)	1.000††
Normal	5 (27.8)	3 (30.0)	2 (25.0)	
Risk factors (at least one)	14 (77.8)	8 (80.0)	6 (75.0)	1.000††
Smoking***	5 (35.7)	3 (37.5)	2 (33.3)	1.000††
HPT***	8 (57.1)	5 (62.5)	3 (50.0)	1.000††
DM***	7 (50.0)	4 (50.0)	3 (50.0)	1.000††
Obesity***	4 (28.6)	3 (37.5)	1 (16.7)	0.58††
Comorbidities				
Yes****	7 (38.9)	3 (30.0)	4 (50.0)	0.63††
No	11 (61.1)	7 (70.0)	4 (50.0)	
Surgery time (min)	227.2±43.9	233.5±38.4	219.4±51.6	0.514†
ECC time (min)	52.3±12.9	52.1±17.2	52.5±4.93	0.95†
Aortal clamping time (min)	41.4±9.46	41.6±11.7	41.2±5.42	0.389†

X-ray: chest X-ray; HPT – systemic arterial hypertension; DM – diabetes mellitus; ECC – extracorporeal circulation. *drugs – atenolol: n=8, 80% (3 in the intervention group, 5 in the control group); enalapril: n=2, 20% (1 in the intervention group, 1 in control group); sinvastatina: n=6; 60% (3 in intervention group, 3 in control group); captopril: n=3, 30% (all in intervention group); furosemide: n=1, 10% (intervention group). ** X-ray changes: infiltrate: n=7, 53.8% (3 intervention group, 4 control); pleural effusion: n=6, 46.2% (2 intervention group, 4 control); atelectasis: n=5, 38.5% (3 intervention group, 2 control). *** percent is calculated over all subjects with at least one risk factor. **** comorbitidies: mitral valve disease: n=1, 14.3% (control); renal failure: n=2, 28.6% (1 intervention group, 1 control); chronic obstructive pulmonary disease: n=6, 85.7% (3 intervention group, 3 control); brain stroke: n=1, 14.3% (intervention group); bronchopneumonia: n=1, 14.3% (control group); hypothireoidism: n=1, 14.3% (intervention group). † independent samples Student t test value. †† exact Fisher's test.

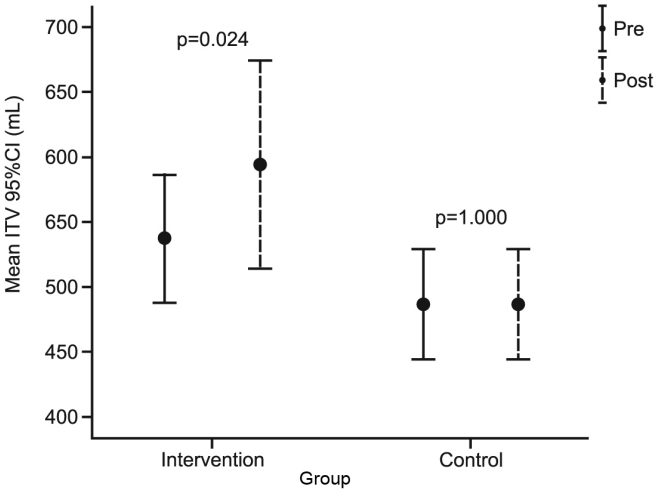
Table 2 – Post-maneuver phase interest outcomes – inter-groups comparison

Variables	Intervention group (N=10) Mean±SD	Control group (N=8) Mean±SD	Difference (95% CI)	P value
SpO_2 (%)	99.4±1	98.1±2	1.3 (-0.22 to 2.77)	0.089†
RR (crpm)	17.3±2.5	18.5±2.2	-1.2 (-3.59 to 1.19)	0.302†
I:E – n(%)				
1:2	8 (80.0)	7 (87.5)	-7.5% (-21% to 13.5%)	1.000††
1:3	1 (10.0)	0 (0.0)	10% (-11.8% to 9.33%)	
1:4	0 (0.0)	1 (12.5)	-12.5% (-11.9% to 9.33%)	
2:1	1 (10.0)	0 (0.0)	10% (-11.8% to 9.33%)	
PPeak (cmH_20)	20.2±2.6	20.4±3.8	-0.2 (-3.00 to 3.35)	0.908†
PPlat (cmH_20)	19.2±2.4	18.3±3.4	0.6 (-2.70 to 3.85)	0.714†
PaO_2 (mmHg)	146±36.0	152±94.4	-6 (-74.4 to 62.4)	0.854†
Extubation time (min)	382±122	359±63.8	23 (-119 to 166)	0.728†
Pos-operative X-ray– n(%)				
Changed*	5 (50.0)	6 (75.0)	-25% (-36% to 8.8%)	0.367††
Normal	5 (50.0)	2 (25.0)	25% (-8.8% to 36%)	
Death – n(%)	0 (0.0)	1 (12.5)	-12.5% (-11.9% to 9.33%)	0.444††

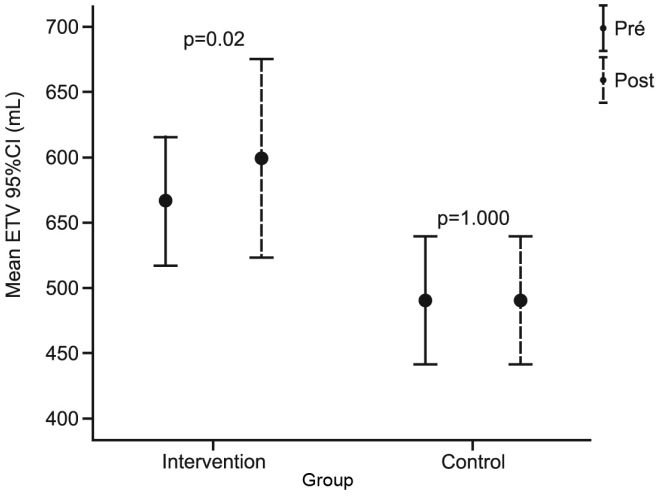
SpO_2 – peripheral oxygen saturation; RR – respiratory rate; I:E – inspiration/expiration rate; PPeak – peak pressure; PPat – plateau pressure; PaO_2 – partial oxygen pressure; X-ray: chest X-ray *chest X-ray changes: infiltrate: n=7, 63.6% (3 intervention group, 4 control); pleural effusion: n=6, 54.5% (2 intervention group, 4 control); atelectasis: n=2, 18.2% (control group). † Independent samples Student t test. †† Exact Fisher's tests.

The oxygenation evaluated by arterial oxygen pressure (PaO_2) averaged 146.0±36.0 mmHg in the intervention group and 152.0±94.4 mmHg in the control group. Again, this difference (-6.0 mmHg (-74.4-62.4 mmHg) was non-significant (p=0.085).

The inspired tidal volume, from the mechanical ventilator, averaged 594±112 mL in the intervention group and 487±51 mL in the control group. This difference (107 mL (15.8-198.0 mL)) points to increased volume in the intervention group (p=0.024) (Figure 1). The expired tidal volume, from the mechanical ventilator, averaged 598.0±10.50 mL for the intervention and 490.0±58.2 mL for the control groups, respectively. This difference (108 mL (19.8-196.0



*statistically significant difference versus control group (p=0.024).



*statistically significant difference versus control group (p=0.02).

Figure 1 - Comparison between the intervention and control groups for inspired and expired tidal volume.

mL)) also points to increase in the intervention group (p=0.02) (Figure 2).

The mean static compliance (Cst) was 39.6±11.6 mL/cmH_2O for the control group. In the intervention group, pre-maneuver the Cst value was 41.6±12.1 mL/cmH_2O and post-maneuver 47.4±16.6 mL/cmH_2O, an statistically significant difference (p=0.03) (Figure 3).

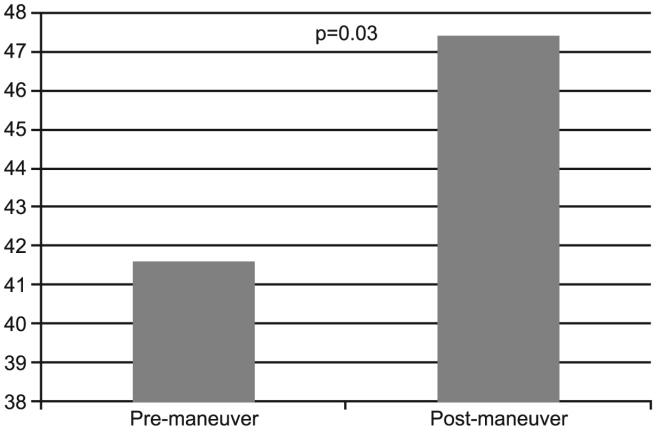


Figure 2 – Static compliance values comparison pre- and post-manual hyperinflation maneuver (mL/cmH_2O).

The mean time to extubation was 382±122 minutes in the intervention group, and 359±63.8 minutes for the control group. This difference (23 minutes (-119-166 minutes)) was non-significant (p=0.728).

Regarding radiological changes, lung infiltrate and pleural effusions were found in both groups and were less prevalent in the intervention group, and atelectasis was only found in the control group. These findings were identified in 50% of the intervention group and 75% of the control group. This difference (25% (-36-8.8%)) was non-significant between the groups (p=0.367).

DISCUSSION

Considering the lack of data on physiotherapy benefits and effectiveness and additionally, on physiotherapeutic handling of mechanic ventilation patients, this study aimed to analyze the outcomes of patients undergoing elective heart surgery regarding extubation time, gases volumes and lung complications to verify if early physiotherapy intervention is favorable for the patient's outcomes. This trial results show a trend of MH maneuver associated with PEEP to promote increased pulmonary volumes and static compliance; however, these findings require further confirmation with a larger sample, to allow drawing conclusions.

According to some trials, prolonged mechanic ventilation leads to several respiratory complications, which in turn are responsible for increased post-heart surgery morbidity and mortality.[17,18] The effects of physiotherapy on mechanic ventilation time and ICU stay have been studied by a number of authors with controversial results. While Templeton and Palazzo[19] showed increased MV time in patients ventilated for longer than 48 hours, Malkoç et al.[20] in a more recent 510 patients trial, found that physiotherapy had a great impact on ventilatory support time and ICU stay.

There were no significant between groups differences regarding peripheral oxygen saturation, perhaps due to the reduced sample size. However, this would trend to be a relevant manual hyperinflation maneuver associated with PEEP gain. This study results agree with the literature on the post- heart surgery respiratory physiotherapy effects.[7]

Oxygenation as evaluated by PaO_2 hadn't significant difference for pre- and post-maneuver values. On the other hand, studies highlight the relevance of analyzing this associated to FiO_2 variable as an important determinant of the results obtained with the maneuver, aiming to increase the gas exchanges at the lung parenchyma level.[21-23]

The inspired tidal volume (ITV) and expired tidal volume (ETV) from the mechanic ventilator had statistically significant increase in the intervention group, suggesting some effectiveness of the manual hyperinflation maneuver associated with PEEP in the post-operative period of coronary bypass surgery. According to Choi and Jones, this maneuver promotes airway resistance reduction, and static pulmonary compliance increase, which are directly related with the increased lung volumes found in the trial.[24]

Static pulmonary compliance had a statistically significant increase from the pre-maneuver to the post-maneuver phase. This finding agrees with other trials' results, with increased Cst following MH.[24-26]

The time to extubation in the intervention group was not significantly different versus the control group, possibly due to the small sample size and the fact that one of the intervention group subjects remained for a longer time under mechanic ventilation due to transoperative lung complications. If this complication was excluded, i.e., if this subject's mechanic ventilation time was similar to the overall group, this difference would trend to be statistically significant. Meade et cols, in 2002, compared early and late post-operative extubation in cardiovascular surgery, concluding that

early extubation prevents mechanic ventilation-associated complications and may reduce hospital stay.[27]

Regarding radiological changes, lung infiltrate and pleural effusion were found in both groups, although less prevalent in the intervention group, and atelectasis was only seen in the control group. Although no significant inter-groups difference was seen in this trial, the literature highlights the importance of this diagnosis tool for the choice of therapy and techniques to be used.[28,29]

Potential limitations were present, such as a period of technical problems in the hemodynamics department, preventing hemodynamic tests; this, in turn, prevented more robust data. We suggest continuing the data collection for more conclusive results.

CONCLUSION

The results show a trend of lung hyperinflation maneuver associated with PEEP to promote increased pulmonary volumes and static compliance. However these findings require further confirmation.

RESUMO

Objetivo: Verificar os efeitos da manobra de hiperinsuflação manual associada à pressão positiva expiratória final em pacientes submetidos à cirurgia de revascularização do miocárdio

Métodos: Ensaio clínico randomizado realizado entre agosto de 2007 e julho de 2008 na unidade de terapia intensiva do Hospital Luterano (ULBRA). Os pacientes foram divididos em grupo intervenção, no qual foi aplicada a manobra de hiperinsuflação manual associada à pressão positiva expiratória final, e grupo controle. As variáveis ventilatórias foram mensuradas em dois momentos: pré-manobra e pós-manobra. Foram utilizados os testes t de Student para amostras independentes e pareadas, bem como os testes exato de Fisher e o qui-quadrado de McNemar.

Resultados: Foram incluídos 18 pacientes durante o período de estudo, com idade média de 64±11 anos, sendo que houve predomínio do sexo feminino (55,6%). O volume corrente inspirado foi de 594±112 ml no grupo intervenção e 487±51 ml no grupo controle (p=0,024) e o volume corrente expirado de 598±105 ml no grupo intervenção e 490± 58 ml no grupo controle (p=0,02). A média da complacência pulmonar estática no grupo intervenção pré-manobra foi de 41,6±12,1 ml/cmH_2O e pós-manobra de 47,4±16,6 ml/cmH_2O (p=0,03). Não houve diferença significativa entre os grupos nas seguintes variáveis: saturação periférica de oxigênio, pressão arterial de oxigênio, tempo de extubação e alterações radiológicas.

Conclusão: Os resultados demonstram uma tendência da manobra de hiperinsuflação manual associada à pressão positiva expiratória final promover aumento dos volumes pulmonares e da complacência estática, entretanto estes achados necessitam confirmação.

Descritores: Terapia respiratória; Reabilitação; Respiração artificial; Exercícios respiratórios; Modalidades de fisioterapia; Respiração com pressão positiva; Revascularização miocárdica

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