ORIGINAL ARTICLE

Braz J Cardiovasc Surg 2005; 20(3): 310-316

Evaluation of pulmonary function in patients following on- and off-pump coronary artery bypass grafting

Avaliação da função pulmonar em pacientes submetidos à cirurgia de revascularização do miocárdio com e sem circulação extracorpórea

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RBCCV 44205-764

Abstract

Objective: **To evaluate and compare the pulmonary function in patients following on- and off-pump coronary artery bypass grafting (CABG).**

Method: **Thirty patients (mean age 56.76 ± 10.20 years) were allocated to two groups, according to the use or not of cardiopulmonary bypasses: group A (n=15) off-pump and group B (n=15) on-pump, with all patients undergoing pre- and post-operative evaluation of the pulmonary function as well as arterial blood gases analysis. Forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV_1) were recorded in the preoperative period, and on the first, third and fifth postoperative days. Blood gases were evaluated in the preoperative period and on the first postoperative day.**

Results: **In both groups, significant falls in the FVC and FEV_1 were detected up to the fifth postoperative day ($p<0.05$). When both groups were compared, the decreases in FCV and VEF_1 were higher in group B ($p<0.05$). PaO_2 values and the PaO_2/FiO_2 ratio presented significant drops on the first postoperative day in both groups, however the fall was higher in group B ($p<0.05$).**

Conclusion: **Patients who undergo CABG, regardless of the use of CPB, display a significant reduction in the postoperative pulmonary function. However, patients who undergo off-pump CABG have a better preservation of the lung function compared to on-pump CABG.**

Descriptors: **Myocardial revascularization. Extracorporeal circulation. Respiratory function tests.**

Resumo

Objetivo: **Avaliar e comparar a função pulmonar em pacientes submetidos à cirurgia de revascularização do miocárdio (RM) com e sem circulação extracorpórea (CEC).**

Método: **Trinta pacientes (média de idade 56,76±10,20 anos) foram alocados em dois grupos, de acordo com a utilização ou não da CEC: grupo A (n=15) sem CEC e grupo**

Work performed in the Pirajussara and São Paulo Hospitals Cardiovascular Surgery and Cardiology Services, Paulista Medical School –Federal University de São Paulo

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Article received in March, 2005
Article accepted in June, 2005

B (n =15) com CEC. Todos os pacientes foram submetidos à avaliação da função pulmonar. Registros espirométricos da capacidade vital forçada (CVF) e do volume expiratório forçado no primeiro segundo (VEF_1) foram obtidos no pré, primeiro, terceiro e quinto dias de pós-operatório (PO) e a gasometria arterial em ar ambiente, no pré e primeiro dia de PO.

***Resultados:* Em ambos os grupos, houve queda significativa da CVF e do VEF_1 até o quinto dia de PO (p<0,05). Quando comparados, a diferença entre os grupos se manteve significativa, com maior queda dos valores de CVF e VEF_1 no grupo B (p<0,05). A PaO_2 e a relação PaO_2/FiO_2 apresentaram queda significativa no primeiro dia de PO em ambos os grupos, porém com maior decréscimo no grupo B (p<0,05).**

***Conclusão:* Pacientes submetidos à cirurgia de RM, independentemente do uso da CEC, apresentaram comprometimento da função pulmonar no PO. Entretanto, os pacientes operados sem uso da CEC demonstraram melhor preservação da função pulmonar, quando comparados àqueles operados com CEC.**

***Descritores:* Revascularização miocárdica. Circulação extracorpórea. Testes de função respiratória.**

INTRODUCTION

In spite of technological advances, pulmonary dysfunction in the postoperative period of coronary artery bypass grafting (CABG) related to the use of cardiopulmonary bypass (CPB) is still one of the most important causes of morbidity [1]. The involvement of the pulmonary function after heart surgery is multifactorial. Additional to the effects of sternotomy and the use of the left internal thoracic artery grafts (LITA) [2], which frequently results in pleurotomy and the necessity of a pleural drain [3], CPB has been seen to aggravate injury and delay recovery of the respiratory function [4]. CPB induces an inflammatory response, causing an increase in the endothelial and pulmonary parenchymatous injury, contributing to the appearance of atelectasis, an increase in the shunt and reductions of both pulmonary complacency and gas exchange [1,5,6].

Over the last few years, new off-pump surgical techniques have been developed, showing an attenuated inflammatory response when compared to the on-pump surgery [7,8]. Studies have demonstrated that off-pump CABG better preserve the pulmonary function [9] and reduce morbidity [7,8], giving a reduction in respiratory complications [10]. However, different authors have reported divergent results when comparing the pulmonary function after on-pump and off-pump surgeries [11,l2].

The aim of this study was to evaluate and to compare the pulmonary function in patients who underwent on-pump and off pump CABG.

METHOD

This study, performed in the Pirajussara and São Paulo Hospitals of the Federal University in São Paulo, was previously approved by the Ethics Committee for Clinical Research of the institutions. Informed written consent was received from all participants of the study. Thirty patients, three (10%) women and 27 (90%) men, with a mean age of 56.76 ± 10.20 years, ranging from 38 to 74 years, were included in the research. All patients presented with coronary insufficiency confirmed by coronary cineangiographic studies, left ventricular ejection fractions greater than 50% and absence of acute or chronic pulmonary disease. They were submitted to on-pump or off-pump CABG, using LITA and left pleurotomy. The patients were allocated into two groups of 15 individuals in accordance to the use of CPB: Group A was submitted to off-pump surgery and Group B to on-pump surgery. The clinical and demographical characteristics of groups A and B are presented in Table 1.

Table 1. Clinical and demographic characteristics of the A and B Groups in respect to the age, gender, weight, height, body mass index, preoperative pulmonary function and data on the intraoperative period

Variable	Group A N =15	Group B N =15	P-value
Age (years)*	57.53 ± 10.29	56.00 ± 10.50	0.33
Gender (n,%)			
Male	14 (93.30%)	13 (86.36%)	1.00
Female	01 (6.70%)	02 (13.33%)	
Weight (Kg)*	72.13 ± 12.69	78.26 ± 16.65	0.12
Height (cm)*	166.13 ± 6.36	166.67 ± 6.28	0.33
BMI (kg/m2)*	26.12 ± 3.08	28.07 ± 4.62	0.08
Pulmonary function			
CVF (L)*	3.69 ± 0.68	3.66 ± 0.66	0.37
% prev*	102.20 ± 16.64	98.73 ± 11.39	0.43
VEF1 (L)*	2.86 ± 0.47	2.92 ± 0.59	0.14
% prev*	98.89 ± 14.40	96.60 ± 11.41	0.32
PaO2 (mmhg)*	74.40 ± 6.85	77.53 ± 4.14	0.08
PaCO2 (mmhg)*	38.27 ± 3.65	37.87 ± 2.50	0.42
PaO2 /FiO2	360.56 ± 44.53	366 ± 31.97	0.28
Surgery time (min)*	309.3 ± 19.35	313.33 ± 46.55	0.16
IOT time (hours) * *	10.00 ± 0.91	14.86 ± 4.40	0.004
Number of grafts (n)	34 ± 0.79	39 ± 0.82	0.19

Abbreviations: BMI – body mass index; FVC - forced vital capacity; FEV1 - Forced expiratory volume in the first second; prev – expected; PaO2 - partial arterial oxygen pressure; PaO2/FiO2 – ratio between the partial oxygen pressure and the inspired oxygen fraction; PaCO2 – partial arterial carbon dioxide pressure; OTI – orotracheal intubation. * mean values ± standard deviation – Mann-Whitney test - ** p-value < 0.05

Preoperative period

The data of the patient's history and physical examination were registered in a detailed report card, including diagnosis, risk factors for coronary disease (systemic arterial hypertension, diabetes mellitus, dyslipidemia and smoking) and associated diseases. Also the pulmonary function was evaluated by spirometry and arterial gasometer. The nutritional state was determined by the analysis of body mass index (BMI), calculated by the ratio weight/(height)^2, as recommended by the World Health Organization [13]. The spirometric evaluation consisted of the measurement of the forced vital capacity (FVC) and forced expiratory volume in the first second (FEV_1), in accordance to the standards of the American Thoracic Society [14]. Values of the FVC and FEV_1 were obtained in the pre-operative period and on the 1st, 3rd and 5th post-operative days, using the Medgraph Ltda Spirobank G portable spirometer. The partial oxygen pressure in the arterial blood (PaO_2) and the ratio between the partial oxygen pressure and the inspired oxygen fraction (PaO_2/FiO_2) were determined in the preoperative period and on the first postoperative day in normal air conditions, always before performing spirometry. All patients were submitted to chest radiography with both posteroanterior and side views. At the end of the preoperative evaluation, the patients received guidance about the surgery, the immediate postoperative period and the importance of respiratory exercises and the necessity to start to walk soon after the procedure.

Intraoperative period

The CABG was performed by median sternotomy, using LITA and left pleurotomy, complemented with additional saphenous vein grafts.

The anesthetic technique employed was the normal system used in the services. All patients were ventilated with current volume of from 8 to 10 mL/kg, without positive end-expiratory pressure (PEEP) and FiO_2 of 100%.

In Group B patients, the cardiopulmonary bypass was established with cannulation to the ascending aorta and venous drainage through the cava, after systemic heparinization at 4 mg/kg, which was repeated depending on the ACT (activated coagulation time), with the aim of maintaining it at over 450 seconds.

In all cases membrane oxygenators were used, together with cardiotomy reservoirs and arterial line filters. The bypass circuit was washed with ringer lactate solution before of filling with the perfusate. Myocardial protection was achieved using intermittent anterograde hypothermic sanguineous cardioplegia, associated with moderate hypothermia (30ºC).

In the patients of the off-pump group (Group A), the technique of the service was followed with systemic heparinization (4 mg/kg) [15]. Occlusion of the coronary artery was achieved using a proximal tourniquet of 4-0 polypropylene thread passed through a malleable silicone tube. Subsequently, depending on the graft, side clamping of the ascending aorta was achieved to perform the proximal anastomosis. An Octopus® 3 (Medtronic, Inc®) suction stabilizer was utilized in all cases.

The left pleural space was drained with a straight tubular PVC drain inserted and exteriorized at the intersection of the sixth left intercostal space with the medial axillary line. In all patients, a mediastinal tubular drain was also left exteriorized through the subxiphoid region.

At the end of the surgery, the patients were taken to the postoperative heart surgery unit (POU) with orotracheal intubation (OTI). Initially, they were ventilated with 100% FiO_2, with a volume of from 8 to 10 mL/kg, PEEP of 5 cmH_2O and extubated according to the protocol of the unit.

Postoperative period

The two groups were reevaluated according to the pulmonary function in the first, third and fifth postoperative days. All patients were submitted to a program of daily physiotherapy until hospital discharge. The aforementioned evaluations were performed always by the same professional, in both the preoperative period and the postoperative period.

Statistical analysis

The Mann-Whitney test was applied to verify that the samples were homogenous. The parameters of pulmonary function were analysed by non-parametrical tests: Friedman's test compared the tendencies over time within each group; the Wilcoxon's test compared two by two intra-group values and the Mann-Whitney test compared values between groups. For all the statistical tests, the level of significance was an alpha < 0.05, that is 5%.

RESULTS

The results did not present statistically significant differences in accordance to age, gender, BMI, preoperative pulmonary function, surgical time and number of grafts. The OTI time of Group A was significantly less than Group B (Table 1). The mean time of CPB in Group B was 109.10 ± 40.82 minutes.

In both groups, there was significant drop in the FVC up to the 5th postoperative day (p-value < 0.05). When comparing the groups together, the difference continued to be significant, always with the greatest drop in Group B. The percentages of the FVC on the first postoperative day compared to the preoperative values in Groups A and B were 33.36 ± 8.34% and 25.60 ± 5.39% respectively, showing a reduction of 66.64% of the FVC in Group A, a loss significantly less than the 74.40% seen in Group B (p-value = 0.003). On the 3rd postoperative day, the drop in percentages of the FVC in Groups A and B were 45.42 ± 7.06% and 37.10 ± 8.55% respectively, showing a drop of 57.58% in Group A and a larger decrease of 62.89% in Group B (p-value = 0.004). The percentages of the FVC on the 5th postoperative day for Groups A and B were 55.13 ± 8.30% and 46.51 ± 8.26% respectively showing that the difference continued significant, with a reduction of 44.87% in Group A and 53.50% in Group B (p=0.004) – Figure 1.

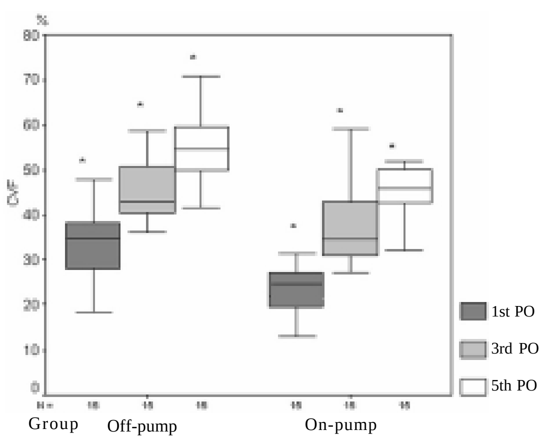

*Fig. 1 - Distribution of the percentage changes in the FVC on the 1st, 3rd and 5th postoperative days (PO), according to the preoperative values, comparing the groups that underwent on-pump and off-pump CABG, considering the initial value in the preoperative period as 100%. * p-value < 0.05*

In both groups, there were significant decreases in the values of FEV_1, up to the 5th postoperative day (p-value < 0.001). Comparing the values obtained in the two groups on the 1st, 3rd and 5th postoperative days, the differences persisted, always with the greatest loss seen in Group B. The percentages of the FEV_1 on the 1st postoperative day of Groups A and B were 35.70 ± 8.66% and 25.48 ± 7.01% respectively, indicating a reduction of 64.30% in Group A, a loss significantly less than the 74.52% of Group B (p= 0.002). On the 3rd postoperative day the percentage drops in Groups A and B were 48.04 ± 7.22% and 40.02 ± 8.59% respectively, indicating a drop of 51.96% in Group A, and a greater decrease of 59.98% in Group B (p=0.004). The percentages of the FEV_1 on the 5th postoperative day in Group A and B were 58.80 ± 8.51% and 49.77 ± 9.26% respectively, indicating that the difference remained significant with a drop of 41.2% in Group A and 50.23 in Group B (p=0.005) - Figure 2.

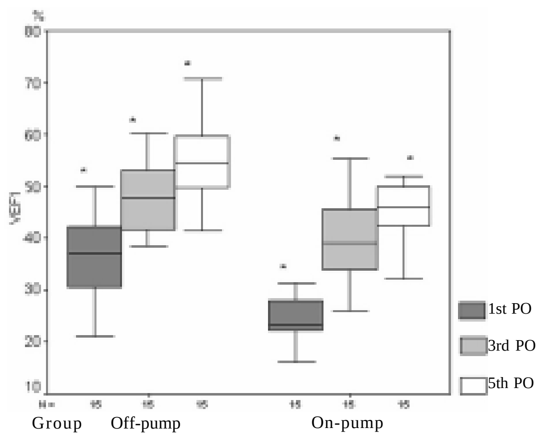

*Fig. 2 – Distribution of the percentage changes in the FEV1 on the 1st, 3rd and 5th postoperative days according to the preoperative values, comparing the groups that underwent on-pump and off-pump CABG, considering the initial value in the preoperative period as 100%. * p-value < 0.05*

There was a significant drop in the PaO_2 on the 1st postoperative day for both groups (p<0.05), but Group A maintained higher values than Group B. The percentages of the PaO_2 on the 1st postoperative day when compared to the preoperative period in Groups A and B were 78.17 ± 9.15% and 69.64 ± 6.32% respectively, indicating a reduction of 21.83% in Group A and 30.36% in Group B (p-value = 0.006) – Figure 3. On the 1st postoperative day, there were also important drops in the PaO_2/FiO_2 ratio in both groups (p=0.001), but Group A gave a value of 275.40 ± 32.05 significantly higher than Group B at 256.20 ± 22.6 (p=0.042) – Figure 4.

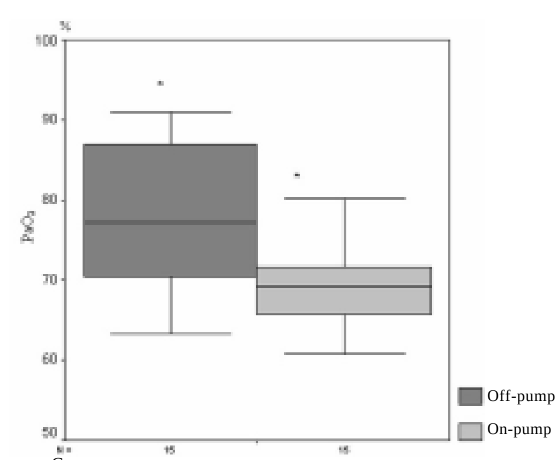

*Fig. 3 – Distribution of the percentage changes in the PaO2 on the 1st postoperative day in relation to the preoperative values, comparing the groups that underwent on-pump and off-pump CABG, considering the initial value in the preoperative period as 100%. * p-value < 0.05*

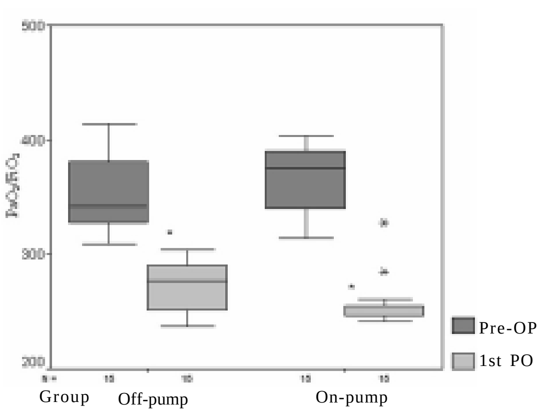

*Fig. 4 – Distribution of the changes of the PaO2/FiO2 ratio on the 1st postoperative day (PO) according to the preoperative values, comparing the groups that underwent the on-pump and off-pump CABG, considering the initial value in the preoperative period as 100%. *p<0.05*

COMMENTS

The present study demonstrated that damage to the pulmonary function is seen in the postoperative period of coronary artery bypass grafting using LITA grafts and pleurotomy, independent of the use of the CPB or not.

The reduction in the pulmonary function is the result of multiple factors from surgical procedures, such as: the general anesthesia, median sternotomy, CPB, diaphragmatic dysfunction and pain, as well as the additional factor of the pleural drainage due to the use of the LITA with pleurotomy [2,16]. The location of the pleural drain can also influence the degree of changes of the pulmonary function [3]. Early studies indicated that, independent of the surgical technique used, CPB increases pulmonary injury and delays recovery [4]. Although some studies show that the morbidity related to coronary artery bypass grafting is attributed to the CPB [1,7,17] and other studies indicate that the procedure without CPB attenuates the inflammatory response with consequently improves the pulmonary function [7-9]. CPB as an aggravator of pulmonary dysfunction in the postoperative period is still controversial [11,12].

Confirming early findings, this study demonstrated that there is more severe pulmonary dysfunction in the procedure with CPB. In accordance with the volumes and pulmonary capacities, there was a significant drop in these parameters up to the 5th postoperative day in both groups, with deterioration of the FVC and FEV_1. However, the group that did not undergo CPB presented with a smaller drop, when compared to the group that underwent CPB. Similar results were described by Silva et al. [18] when comparing these values on the 4th and 10th postoperative days. Vargas et al. [2] found a reduction in the FVC of around 70% on the 1st postoperative day in patients who underwent on-pump CABG, a similar result to our study. Tschernko et al. [9] reported better values of complacency and pulmonary volumes after the off-pump procedure, concluding that the off-pump technique offers better protection to the pulmonary function. Although pulmonary complacency was not evaluated in this study, a greater drop in the FVC in the On-pump Group might be attributed to lower complacency.

Babik et al. [19] showed that CPB increases the resistance of the airway tracts when compared to the off-pump procedure. Similar results were observed by Cogliati et al. [20] in on-pump surgeries, in which a reduction in the pulmonary complacency was evidenced, increasing the pressure of apex in the airway tract, indicating more resistance of the respiratory system, which could justify the greater reductions in the FEV_1 and FVC found in this study. Staton et al. [21] demonstrated a significant reduction in spirometer parameters independent of CPB, however, when comparing between the On-pump and Off-pump Groups there was no significant difference, different to the result found in our study. Kirklin [22] reported that the majority of the effects of CPB in relation to the pulmonary function continue for approximately five days after the surgery. This fact can explain the results of the aforementioned study, which evaluated spirometry from four to six weeks after surgery.

Arterial hypoxemia normally occurs after CABG and persists for some weeks independent of CPB [23]. But this dysfunction in gas exchange is found more accentuated in on-pump CABG [6]. In this study, we observed a significant drop in the PaO_2 and the PaO_2/FiO_2 ratio in both groups; the group that underwent CPB presented a greater drop in the values when compared to the Off-pump Group. Tschernko et al. [9] demonstrated that off-pump surgery is capable of reducing the shunt and increasing oxygenation when compared to on-pump procedures. A similar result was reported by Staton et al. [21], where off-pump surgeries gave better preservation of gas exchange in the postoperative period. Not all authors found significant differences in the pulmonary function test and gas exchange between On-pump and Off-pump Groups, but in spite of not being significant, the group that underwent off-pump surgery still presented with better values [11,12].

The mechanism of hypoxemia can be attributed to several factors, such as a change in the ventilation/perfusion ratio, hypoventilation, reduction in the diffusion capacity and shunts with the latter being the best documented in the immediate postoperative period after CPB [23]. The possible causes of increases in shunts in on-pump CABG may be related to a reduction in the pulmonary complacency and FVC [16,23]. The contact of the blood with the oxygenator triggers a cascade effect of enzymatic changes, with the release of inflammatory cytokines, increases in the permeability of the alveolar-capillary membrane, reducing the production of alveolar surfactant and diffusion by the blood-gas membrane, which harms the pulmonary complacency and consequently, the pulmonary volume and the gas exchange [1,5,9]. These factors might explain in our study the highest drop in the oxygenation in the group that underwent CPB, due to a greater decrease in the FVC. Other factors contribute to the greater involvement of the respiratory function. During CPB it is common to interrupt the pulmonary ventilation, as there is insufficient alveolar insufflation to active the production of surfactant by type II pneumocytes, thereby increasing the surface tension, which can cause alveolar collapse [5].

CPB can even increase the degree of diaphragmatic dysfunction. Currently, one of the most accepted explanations to justify the reduction in the FVC after thoracic surgery is diaphragmatic dysfunction. This dysfunction starts in the manipulation of the viscera during the surgical procedure, causing reflex inhibition of the phrenic nerve and diaphragmatic paresis [24]. Some studies have shown that the cardioplegic solution may cause thermal injury to the phrenic nerve. The cold can result in functional and structural abnormalities, damaging the conduction velocity, increasing the degree of diaphragmatic paresis, which may contribute with a greater drop in the pulmonary volumes and capacities [4, 16, 23]. Several researchers have shown advantages in off-pump CABG, mainly in respect to a reduction of the postoperative morbidity rate [7,8,17], reduction in the orotracheal intubation time [7,8,17,21], a reduction in respiratory complications [10] and, consequently, a shorter time in hospital [9,17] associated with a reduction in the hospital costs [8]. In this study, the time of orotracheal intubation of the patients who underwent the off-pump surgery was significantly shorter than the On-pump Group, similar to reported results, associating better preservation of the pulmonary function to a shorter intubation time [9,17].

The greater the drops in the FVC and FEV_1 were, the greater was the possibility of damage to the pulmonary function, leaving the respiratory system vulnerable to complications [25]. Changes in the gas exchange and pulmonary mechanics increase the respiratory effort, favoring an accumulation of secretion, with a higher possibility of obstruction to the airflow, which may predispose the patient to atelectasis and pneumonia [4,5]. In this study, in spite of not being evaluated, patients who underwent CPB may be susceptible to a higher complication rate in the postoperative period, as they present with a greater drop in the spirometric and gas exchange parameters.

CONCLUSION

Patients, who underwent CABG, independent of the use of CPB, presented with compromise to the pulmonary function in the postoperative period. However, the patients operated on without the use of CPB demonstrated a better preservation of the pulmonary function when compared with the patients operated on under CPB.

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