Available online at www.sciencedirect.com

ScienceDirect

Journal of the Egyptian Society of Cardio-Thoracic Surgery 24 (2016) 15–20
http://www.journals.elsevier.com/journal-of-the-egyptian-society-of-cardio-thoracic-surgery/

Original article

Immediate pulmonary dysfunction in ischemic heart disease patients undergoing off-pump versus on-pump CABG

Ashraf Helal Abd-Allah [a], Ahmed Abd El-Rahman Mohamed [a], Samy Mahmoud Amin [a,*], Samah Selim [b], Mohamed Allam [a]

[a] *Department of Cardiothoracic Surgery, Faculty of Medicine, Cairo University, Egypt*
[b] *Department of Chest Diseases, Faculty of Medicine, Cairo University, Egypt*

Available online 16 June 2016

Abstract

Background: Many studies have shown important changes in lung function tests after coronary artery surgeries. It is controversial if off-pump surgery can give a better and shorter recovery than the on-pump. The aim of this work was to study immediate early pulmonary dysfunction in ischemic heart disease patients undergoing off-pump versus on-pump coronary artery bypass grafting (CABG) in order to evaluate pulmonary dysfunction caused by cardio-pulmonary bypass (CPB) in patients undergoing on-pump CABG.

Patients and method: A prospective randomized study was carried out on 40 patients submitted to coronary artery surgery at Kasr El-Aini University Hospital, Cairo, Egypt. They were randomly divided into two groups; group A: 20 patients undergoing CABG using heart-lung machine (on-pump), and group B: 20 patients undergoing off-pump CABG. All patients had: spirometric evaluation, 6 min walk test pre-operatively and at the post-operative fifth day. Measurement of arterial blood gases (ABGs) and calculation of P/F ratio was recorded pre-operative, post-induction and post CABG. Post-operative intensive care unit (ICU) events were also assessed.

Results: Post-operative spirometric data and 6 min walk distance decreased in both groups, when compared to pre-operative values, with significant differences between the two groups. No significant reduction in arterial oxygen pressure (PaO_2), carbon dioxide pressure ($PaCO_2$) and P/F Ratio occurred post-operatively.

Conclusion: Pulmonary functions deteriorate significantly after coronary artery revascularization with and without CPB, but to a significant greater reduction among those on-pump than among those off-pump surgeries.

Keywords: Coronary heart disease; Coronary artery bypass surgery; Pulmonary function tests; Cardio-pulmonary bypass

* Corresponding author. Tel.: +20 1000084643 (mobile); fax: +20 24795300.
E-mail address: samymamin@yahoo.com (S.M. Amin).
Peer review under responsibility of The Egyptian Society of Cardio-thoracic Surgery.

http://dx.doi.org/10.1016/j.jescts.2016.04.005

1. Background

Post-operative pulmonary dysfunction in patients undergoing CPB is a significant clinical problem and has long been recognized by cardiac surgeons, anesthetists, and intensive-care physicians [1].

The physiologic disturbance after CPB can be categorized grossly into abnormal gas exchange and poor lung mechanics [2]. However, the most significant proportion of this impairment is due to CPB which usually leads to excessive interstitial pulmonary edema and subsequent abnormal gas exchange [3].

The aim of the work was to study early immediate pulmonary dysfunction in ischemic heart disease patients undergoing off-pump versus on-pump CABG to evaluate pulmonary dysfunction caused by CPB in patients undergoing on-pump CABG.

2. Patients and methods

This prospective study was performed at Kasr El Aini Hospital, Cairo University, in Egypt in the period between June 2014 and February 2015. The study was previously approved by the Ethics Committee for Clinical Research of the institutions. Informed written consent was received from all participants of the study.

Forty patients, 8 women and 32 men, with a mean age of 56.5 ± 6.05 years, were included in the study. All patients presented with coronary insufficiency confirmed by coronary angiographic studies, and absence of restrictive or chronic pulmonary disease or history of any pulmonary diseases. The patients were allocated randomly into two groups; each consisted of 20 individuals in accordance to the use of CPB; Group A was submitted to on-pump surgery, and Group B to off-pump surgery.

All patients were evaluated thoroughly pre-operatively, intra-operatively and post-operatively. Particular attention was paid to findings of pulmonary function parameters (spirometric data and 6 min walk test results). Spirometry was performed to all subjects using ZAN 100 Spirometry System at the pulmonary function unit in Chest Department. The spirometric evaluation consisted of the measurement of the forced vital capacity (FVC) % and forced expiratory volume in the first second (FEV1) % and forced expiratory flow (FEF) 25–75% and FEV1/FVC ratio in accordance to the standards of the American Thoracic Society [4]. Six minute walk test was done for all patients and the distance were recorded [5]. Values were obtained in the pre-operative period and on the fifth day post-operatively. All spirometric data were expressed as a percent of the predicted value. ABGs were taken pre-operatively, post-induction and post CABG. Post-operative ICU events, especially the duration of mechanical ventilation, the use of inotropic agents and the occurrence of pulmonary complications were also assessed.

2.1. Statistical analysis

Data were statically described in terms of mean, standard deviation (±SD), frequencies (number of cases) and relative frequencies (percentages) when appropriate. Comparison of quantities variables between the two groups was done using Mann–Whitney U test. Chi square ($\times^2$) test was performed for qualitative variables. A probability value (P-value) less than 0.05 was considered statistically significant. All statistical calculations were done using SPSS statistical program using Microsoft Excel version 7.

3. Results

There were no significant difference between both groups as regards the age, gender and presence of co-morbidities (diabetes mellitus, hypertention, dyslipidemia, smoking, obesity, stroke, or myocardial infarction). Also the cardiac ejection fraction (EF %) showed no statistical significance among both groups. The number of grafts ranged from two to four in both groups. It was found that the total operation time did not differ significantly between group A compared to group B [(244.5 ± 47.29, 247 ± 41.05) minute; p-value = 0.42].

Pulmonary function assessment in terms of 6 min walk test and spirometry were carried-out for all patients pre-operatively and at the fifth day post-operatively and the results were compared between both groups (Table 1). The distance of 6 min walk test in group A ranged from 400 to 460 m with a mean of 411.5 ± 17.25 m, while group B had a 6 min walk test ranging from 400 to 500 m with a mean of 424 ± 32.67 m. There was no statistical significance between the two groups. All pre-operative spirometric data in terms of mean FEV1%, FVC%, and FEF25-75%, showed no statistical significance among both groups pre-operatively. There were statistical significant differences for 6 min walk distance (SMWD) and all spirometric data between both groups post-operatively. It worth attention that

Table 1
Statistical analyses of 6 min walk distance and spirometric data among all patients.

		Group A (on-pump surgery)	Group (off-pump surgery)	P-value*
SMWD (meter) (mean ± SD)	Pre-operative	411.5 ± 17.25	424 ± 32.67	0.06
	Post-operative	252.5 ± 33.39	329 ± 53.04	<0.01
	P-value	<0.01	<0.01	
	% reduction	40%	22%	<0.05
FEV1% (mean ± SD)	Pre-operative	90.35 ± 7.93	86.2 ± 8.94	0.06
	Post-operative	48.6 ± 10.01	58.45 ± 12.17	<0.01
	P-value	<0.01	<0.01	
	% reduction	46.2%	32.5%	<0.01
FVC% (mean ± SD)	Pre-operative	90.45 ± 5.58%	86.5 ± 9.14%	0.17
	Post-operative	51.5 ± 7.77	61.45 ± 10.94	<0.01
	P-value	<0.01	<0.01	
	% reduction	43.04%	29.3%	<0.01
FEF25-75% (mean ± SD)	Pre-operative	94.05 ± 27.18	86.1 ± 25.92	0.05
	Post-operative	42.5 ± 16.33	55.57 ± 22.67	<0.01
	P-value	<0.01	<0.01	
	%reduction	55.5%	35.3%	<0.01

SMWD: 6 min walk distance, FEV1: forced expiratory volume in the first second, FVC: forced vital capacity, FEF: forced expiratory flow. Significant P-value: less than 0.05.

the mean post-operative SMWD and all spirometric data decreased significantly from pre-operative values in each group with less reduction among group B (off-pump surgery).

Changes of ABG_S all over the study were recorded. ABGs withdrawn pre-operatively for the patients in group A showed that; pH ranged from 7.34 to 7.5 with mean of 7.41 ± 0.05, HCO_3 ranged from 22.6 to 31.2 with a mean of 25.78 ± 2.42, PaO_2 range was from 83 to 102 mmHg with a mean 92.5 ± 5.6 mmHg, the $PaCO_2$ range was from 35 to 47 mmHg with mean 41.5 ± 2.7 mmHg with no statistical significance between the two groups.

The mean values of the parameters of ABGs withdrawn intra-operatively post induction of anesthesia (on FiO_2 100%) were, for the patients in group A; pH 7.41 ± 0.03, HCO_3 25.43 ± 1.93, PaO_2 380 ± 40 mmHg, and $PaCO_2$ 40.3 ± 3.55 mmHg. While in group B; pH 7.4 ± 0.04, HCO_3 25.4 ± 1.5, PaO_2 380.5 ± 48.32 mmHg, and $PaCO_2$ 40.38 ± 2.88 mmHg. There was no statistical significance regarding the difference in the ABGs parameters between the two groups.

ABGs withdrawn post CABG (on FiO_2 100%) for the patients in group A showed that; the mean pH was 7.4 ± 0.05, mean HCO_3 was 25.4 ± 2.98, mean PaO_2 was 300 ± 40.02 mmHg, and the $PaCO_2$ was 41.18 ± 6.6 mmHg. While in group B; mean pH 7.41 ± 0.07, mean HCO_3 was 25.6 ± 3.48, mean PaO_2 303 ± 43.86 mmHg, and the mean $PaCO_2$ was 39.83 ± 6.2 mmHg with no statistical significance regarding the ABGs parameters between the two groups.

The ABGs withdrawn in the ICU for the patients while they were ventilated on FiO_2 40%: in group A showed that mean pH was 7.4 ± 0.07, mean HCO_3 was 24.6 ± 2.23, mean PaO_2 was 132 ± 35.75 mmHg, and the mean $PaCO_2$ was 39.62 ± 5.10 mmHg. While in group B; mean pH was 7.3 ± 0.08, mean HCO_3 was 25.1 ± 2.46, mean PaO_2 was 132 ± 22.33 mmHg, and the mean $PaCO_2$ was 38.37 ± 2.94 mmHg. There was no statistical significance regarding the difference in the ABGs parameters between the two groups.

In the post-operative period after extubation (on FiO_2 21%), the ABGs showed that in group A; the mean values were as the following: pH 7.39 ± 0.05, HCO_3 24.2 ± 1.7, PaO_2 80 ± 8.65 mmHg, $PaCO_2$ 40.95 ± 5.07 mmHg. While in group B; pH 7.4 ± 0.13, HCO_3 25.5 ± 3.16, PaO_2 83.5 ± 6.04 mmHg, $PaCO_2$ 38.6 ± 3.73 mmHg. There was no statistical significance regarding the difference in the ABGs parameters between the two groups.

The changes in the mean PaO_2/FiO_2 ratios were presented in Fig. 1. The PaO_2/FiO_2 ratio measured before induction of anesthesia was comparable between both groups (Group A: 440.5 ± 26.65, Group B: 457 ± 24.95; mean ± SD). Similarly, there was no significant difference in the P/F ratio measured after induction of anesthesia. However, it dropped significantly to 300 ± 42.07 in group A and to 303 ± 43.84 in group B immediately post CABG. Thereafter, the P/F ratio gradually improved. There was no statistical significant difference between both groups at any stage during the study.

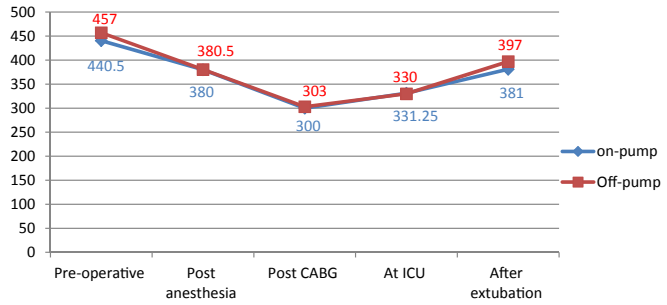

Fig. 1. P/F ratio at all stages of the study. The mean values were expressed (mmHg).

All patients were admitted to cardiothoracic ICU post-operatively and were mechanically ventilated. The duration of post-operative mechanical ventilation ranged from 5 to 13 h with a mean of 8.8 ± 2.08 h in group A, while in group B the duration ranged from 4 to 9 h with a mean of 6.05 ± 1.46 h. There was a statistical significance between the two groups (p-value > 0.01). However, there was no statistical significant difference between both groups as regards the need for inotropic support, significant blood loss, or occurrence of atelectasis and pleural effusion (Table 2). None of the patients in both groups developed pulmonary complications in the form of pneumonia, ARDS, or phrenic nerve paralysis.

4. Discussion

Pulmonary dysfunction in the post-operative period of CABG that is related to the use of CPB is still one of the most important causes of morbidity. Impairment of pulmonary function occurs in the early post-operative period of CABG surgery. The cause of the significant reduction of pulmonary function after CABG surgery is multifactorial [6].

4.1. Pre-operative assessment

Identified risk factors for post-operative respiratory failure included critical pre-operative state, neurologic dysfunction, poor left ventricular function, active endocarditis, chronic obstructive pulmonary disease, elevated pre-operative creatinine, previous cardiac operation, and old age [7]. In the current study, careful pre-operative assessment was carried out. Patients with neurological dysfunction, poor left ventricular function, previous cardiac operation or renal dysfunction were excluded from the study.

Spirometry was done for both groups (Table 1). Regarding FVC; in group A, patients had a mean of 90.45% ± 5.58, while group B, patients had a mean FVC of 86.5% ± 9.14. There was no statistically significant difference between the two groups. Felix et al., 2004 [8] reported mean FVC of 92% for group A and 94% for group B with no statistical significance. Hikmet, 2010 [9] and Guizini et al., 2005 [10] reported almost the same results with no statistical significance.

Regarding the mean FEV1 in our study groups; it was 90.35 ± 7.93% in group A, and 86.2 ± 8.94 in group B. There was no statistically significant difference between the two groups. Felix et al., 2004 [8] reported FEV1 with the mean of 91% for group A and 92% for group B. Hikmet, 2010 [9] and Guizini et al., 2005 [10] also reported almost the same results with no statistical significance.

Table 2
Statistical analysis of post-operative complications.

	Group A (on-pump surgery)	Group B (off-pump surgery)	P-value[a]
Inotropic support (no, %)	5 (25)	7 (35)	0.62
Blood loss (cc, mean ± SD)	230 ± 109.36	282.5 ± 124.22	0.06
Atelectasis (no, %)	7 (35)	6 (30)	0.73
Pleural effusion (no, %)	3 (15)	4 (20)	0.68

[a] Significant P-value less than 0.05.

Regarding the mean FEF 25-75; in group A, it was 94.05 ± 27.18, while group B it was 86.1 ± 25.92. There was no statistically significant difference between the two groups. Felix et al., 2004 [8] reported a mean FEF 25-75 equal 102% for group A and 99% for group B. Hikmet, 2010 [9] and Guizini et al., 2005 [10] also reported almost the same results with no statistical significance.

The ABGs withdrawn pre-operatively for the patients in group A showed that mean PaO_2 was 92.5 ± 5.6 mmHg and mean $PaCO_2$ was 41.5 ± 2.7 mmHg and the mean P/F ratio on FiO_2 21% was 440.5 ± 26.6. While in group B mean PaO_2 was 96 ± 5.23 mmHg, mean $PaCO_2$ equal 39.85 ± 3.46 mmHg and the mean P/F ratio on FiO_2 21% was 457 ± 24.95. There was no statistical significance regarding the difference in the ABGs parameters between the two groups. Serdar et al., 2003 [11] reported almost the same results with mean PaO_2 88 ± 10.13 for group A and 89.4 ± 6.24 for group B and mean $PaCO_2$ 38.1 ± 4.51for group A and 39.17 ± 3.14 for group B with no statistical significance. Felix et al., 2004 [8] reported no statistical significance between P/F ratios in both groups. Guizini et al., 2005 [10] also reported no statistical significance.

4.2. Intra-operative evaluation

Numerous investigators have documented a decrease in pulmonary gas exchange post-operatively in patients undergoing CABG with CPB. The possible causes include; decrease in functional residual capacity, decrease lung compliance, increased shunt caused by leukocyte migration to the lungs, and increased permeability of the alveolar capillary membrane [12–14]. In the current study, both groups showed reduction in mean PaO_2 and P/F ratio post CABG without significant difference.

The mean percent of reduction in PaO_2 in post-induction ABGs when compared to post CABG mean values was 18% ± 10.8 for group A and 16.2% ± 10.2 for group B with no statistical significant difference. This suggested that CPB is not the only factor behind the changes in ABGs.

4.3. Post-operative evaluation

Along our study, no attempt to extubate the patients at the operating theater were made. All patients were admitted to ICU post-operatively and were mechanically ventilated. There was a statistically significant difference between both groups as regards the mean post-operative mechanical ventilation time (8.8 ± 2.08 Vs 6.05 ± 1.46, hours, P-value > 0.01). Hikmet, 2010 [9] and El Naggar et al., 2011 [15] also reported statistical significance. El Naggar et al., 2011 [15] also reported higher need for prolonged mechanical ventilation (>6 h) in on-pump as compared to off-pump group (50% Vs 3.3%, $P < 0.001$).

No significant difference as regards the parameters of ABGs was found between both groups. Similar results were observed in other studies [8,10,11].

In our study group, regarding the mean FVC, in group A it was 51.5% ± 7.77, while in group B it was 61.45% ± 10.94. There was statistically significant difference between the two groups. Guizini et al., 2005 [10] reported the percentages of the FVC on the 5th postoperative day for Groups A and B were 46.51% ± 8.26% and 55.13% ± 8.30%, respectively. Hikmet, 2010 [9] also reported statistical significance with better preservation of functions in group B.

Regarding the mean FEV1 in our study; in group A it was 48.6% ± 10.01, while in group B it was 58.45% ± 12.17. There was a statistically significance difference between the two groups. Guizini et al., 2005 [10] also reported the mean FEV1 in the 5th postoperative day in Group A and B to be 49.77% ± 9.26% and 58.80% ± 8.51, respectively. Almost the same results were found with statistical significance between both groups with greater reduction in group A. Hikmet, 2010 [9] also reported statistical significance with better preservation of functions in group B.

It was also found that the mean SMWD was significantly decreased post-operatively in both groups with mean reduction in group A, 40% ± 9.4 and 22% ± 13.7 in group B, meaning a better preservation in group B.

5. Conclusion

Patients who undergo CABG regardless of the use of CPB, displayed a significant reduction in the post-operative pulmonary functions. However, patients who undergo off-pump CABG had a better preservation of the lung function compared to on-pump CABG. No significant reduction in post-operative arterial blood gases values and P/F ratio compared to pre-operative values occurred among both groups.

Conflict of interest

None.

References

[1] Speekenbrink R, van-Oeveren W, Wildevuur C. Pathophysiology of cardiopulmonary bypass. In: Golstein D, OzM, editors. Minimally invasive cardiac surgery. 2nd ed. Totowa, NJ: HumanaPress; 2004. p. 3–18.
[2] Menasche P, Edmunds LHJ. The inflammatory response. In: Cohn LH, Edmunds LH, editors. Cardiac surgery in the adult. 2nd ed. New York: McGraw Hill; 2003. p. 349–60.
[3] Miller BE, Levy JH. The inflammatory response to cardiopulmonary bypass. J Cardiothorac Vasc Anesth 1997;11:355–66.
[4] Miller MR, Hankinson J, Brusasco V, et al. Standardization of spirometry. Eur Respir J 2005;26:319–38.
[5] American Thoracic Society. ATS statement. Guidelines for the six minute walk test. Am J Respir Crit Care Med 2002;166(1):111–7.
[6] Guizilini Solange, Gomes Walter J, Faresin Sonia M. Influence of pleurotomy on pulmonary function after off-Pump coronary artery bypass grafting. Ann Thorac Surg 2007;84(3):817–22.
[7] Bailey Michael L, Richter Sven M, Mullany Daniel V. Risk factors and survival in patients with respiratory failure after cardiac operations. Ann Thorasic Surg 2011;92(5):1573–9.
[8] Montes Felix R, Maldonado Javier D, Paez Silvia, et al. Off-pump versus on-pump coronary artery bypass surgery and postoperative pulmonary dysfunction. J Cardiothorac Vasc Anesth 2004;18:698–703.
[9] Iyem Hikmet. Comparison of pulmonary functions tests between on-pump and off- pump patients in coronary artery bypass surgery. Cardiol 2010;5(2):12–7.
[10] Guizilini Solange, Gomes Walter J, Faresin Sonia M, et al. Evaluation of pulmonary function in patients following on- and off-pump coronary artery bypass grafting. Braz J Cardiovasc Surg 2005;20(3):310–6.
[11] Cimen Serdar, Özkulb Vedat, Ketencia Bülent, et al. Daily comparison of respiratory functions between on-pump and off-pump patients undergoing CABG. Eur J Cardio-Thoracic Surg 2003;23:589–94.
[12] Singh NP, Vargas FS, Cukier A, et al. Arterial blood gases after coronary artery bypass surgery. Chest 1992;102:1337–41.
[13] Vargas FS, Terra-Filho M, Hueb W, et al. Pulmonary function after coronary artery bypass surgery. Respir Med 1997;91:629–33.
[14] e Silva Ana MRP, Saad Roberto, Stirbulov Roberto, et al. Off-pump versus on-pump coronary artery revascularization: effects on pulmonary function. Interact Cardiovasc Thorac Surg 2010;11:42–5.
[15] El Naggar Ayman, Abou El Magd Maged, El Hoseiny Rania, et al. Off pump versus on pump coronary artery bypass grafting. Perioperative complications and early clinical outcomes. Egypt Heart J 2012;64:43–7.