

Comparison of Pulmonary Function Tests Between On-Pump and Off-Pump Patients in Coronary Artery Bypass Surgery

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Abstract: It aimed to investigate the negative effect of cardiopulmonary bypass on pulmonary function tests in early postoperative term by comparing pre and postoperative pulmonary function tests and level of blood gases. About 134 consecutive patients underwent CABG surgery between January 2008 and November 2009 were enrolled to prospective study. Patients were divided into two groups: group 1 (n = 67) included patients who underwent on-pump cardiac surgery, group 2 (n = 67) included patients who underwent off-pump cardiac surgery. Pulmonary function tests were recorded preoperatively and at postoperative 6th day. The follow-up parameters including Vital Capacity (VC), Forced Expiratory Volume at 1 sec (FEV₁) and FEV₁/VC% of patients in both groups were compared. In present study, 78 males and 56 females overall 134 patients (mean age 62.2±6.4) were evaluated. Overall mortality was 2.98%. Although, there was no difference in FEV₁ level in preoperative period, it was higher with statistical significance in off-pump group compared on-pump group (77.1±4.2 vs. 63.2±4.2, p<0.005, respectively) at postoperative 6th day. FEV₁/VC rate was also higher with statistical significance in off-pump group than on-pump group (88.1±12.1 vs. 66.4±14.2, p<0.001, respectively) at postoperative 6th day while there was no difference in preoperative period. It think that the off-pump technique is more useful not only in high risk patients but also in all patients will undergone CABG surgery when the negative effect of CPB just on pulmonary function tests is considered.

Key words: Coronary artery by-pass graft, on-pump, off-pump, pulmonary function tests, preoperative period, CABG surgery

INTRODUCTION

The negative effects of severe pulmonary disease are known in patients undergoing cardiac surgery. There are lots of reports related to Chronic Obstructive Disease (COPD) which is a risk factor for Coronary Artery by-pass Graft (CABG) surgery (Grover *et al.*, 1990; Cohen *et al.*, 1995). COPD is determined as a risk factor for cardiac surgery in most score systems (Samuels *et al.*, 1998; Roques *et al.*, 1999). COPD is also one of the most common cause for mortality and morbidity in adults population that is a problem affecting preoperative and postoperative success rates. As the changes in pulmonary function is seen in most patients underwent surgery, these changes may also often observed in perioperative period (Auchinclas, 1974). The complications relating respiratory system affect surgery and postoperative recovery process negatively in patients undergoing CABG (Lawrence *et al.*, 1989; Jackson, 1988). It has been reported that morbidity and mortality increased proportional with decrease in levels of pulmonary function test and diffusion capability of blood gases in patients underwent CABG (Gass and Olsen, 1986; Ayres,

1996). Many studies and clinical experience of all cardiovascular surgeons reveal that respiratory problems are common major factors affecting morbidity and mortality CABG. The problems related anesthesia, poor function, cardiac bypass and operation techniques are the most common known reasons for pulmonary complications after CABG (Taggart *et al.*, 1993). In present prospective study, we aimed to investigate the negative effect of cardiopulmonary bypass on pulmonary function tests in early postoperative term by comparing pre and postoperative pulmonary function tests and level of blood gases.

MATERIALS AND METHODS

After the approval of local ethics committee of the institution, a detailed written informed consent about all the procedure was taken from all patients. About 134 consecutive patients underwent CABG surgery between January 2008 and November 2009 were enrolled to prospective study. Patients were divided into two groups: group 1 (n = 67) included patients who underwent on-pump cardiac surgery, group 2 (n = 67) included

Table 1: Extubation criterions

Parameters	Reference values
SBP (mm Hg)	>100 mm Hg
SaO ₂	>90%
PaO ₂ (FiO ₂ = 50%)	>60 mm Hg
PaCO ₂	<45 mm Hg
pH	>7.35
Heart rate	<100 min ⁻¹
Spontan tidal volume	5-7 mL kg ⁻¹

SBP: Systolic Blood Pressure

patients who underwent off-pump cardiac surgery. Patients with COPD had anomalies of skeletal system and history of lung surgery and chronic lung infection excluded from study. The diagnosis of COPD was made by chest physician on based of respiratory function tests as defined in guidelines. Pulmonary function tests were recorded preoperatively and at postoperative 6th day. Blood gases were also recorded preoperatively and 1st day after extubation. Extubation process was made according to criterions that were shown in Table 1. Prolonged mechanical ventilation was defined as if mechanical ventilation duration exceeded 24 h. The follow-up parameters including Vital Capacity (VC), Forced Expiratory Volume at 1 sec (FEV₁) and FEV₁/VC% of patients in both groups were compared. At each examination in follow-up period, arterial analysis of blood gasses (PO₂, PCO₂ and O₂ saturation) were recorded. For all the patients, renal and liver function tests (urea, creatinine, creatinine clearance, SGOT and SGPT) were analyzed in preoperative period and postoperative 1st, 2nd and 3rd days.

Operative technique

Anesthesia: Routine protocol of the cardiovascular surgery clinic was applied to all patients. All routine cardiac medications were continued up until the morning of surgery. In the operation room ECG monitorization and radial artery cannulation for systemic arterial blood pressure monitorization were applied. Peripheral venous line, central jugular vein catheters and urethral catheters were inserted. Body temperature was monitored with rectal and oesophageal probes. Anesthesia was induced with 20 mcg kg⁻¹ fentanyl citrate, 0.12 mg kg⁻¹ pancuronium, 2 mg kg⁻¹ propofol and 2 mg of pancuronium were given every 45 min during the operation. After tracheal intubation, mechanical ventilation was instituted with 6-8 mL kg⁻¹ tidal volume and 10-12 min respiratory rates. Anesthesia was maintained with 10 mcg kg⁻¹ of fentanyl and 1 mg kg⁻¹ propofol as infusion.

On-pump operative technique: After standard median sternotomy, preparation of left internal mammarian arterial flap and greater saphenous vein grafts, 400 IU kg⁻¹

heparin was administered before the institution of CPB. Activated clotting time was managed to be over 400 during CPB. At the end of the CPB the heparin effect was reversed with protamin sulphate at 1/1 ratio.

Then aortic and two stage venous canulla were used to institute the Cardio Bypass (CPB) using a roller pump, membrane oxygenation and identical priming solution. Systemic blood flow was maintained at 2.2-2.4 L m⁻², mean arterial blood pressure at 60-70 mm Hg during CPB. Systemic hypothermia (28°C) and hemodilution were applied. Distal anastomoses were performed during the Cross Clamp (CC) period. Proximal anastomoses were performed with partial occluding clamp in beating heart. Postoperatively pharmacological support was instituted according to hemodynamic requirements. In all patients recieved pericardial (No. 28) and mediastinal (No. 32) chest tubes were inserted aorta-right atrial cannulation and cardio bypass were performed in on-pump patients.

Off-pump operative technique: Left internal mammary artery and saphenous vein grafts were harvested for grafting for off-pump patients. The octopus as myocard stabilizer was used during distal anostomosis. Proximal anostomosis were kept out side clamp.

In all patients ITA was harvested only on the left side. All of the patients recieved mediastinal (No. 32 silicon) and left thorax (No. 32 silicon) tubes for drainage and removed routinely on the 1st postoperative day upon change in the drainage towards serosity. To monitor atelectasis, a chest roentgenogram was performed routinely 1 day before operation and during the first three postoperative days.

Atelectasis were recorded when showing a clear radiologic shadow of a width of >20 mm. Lineer atelectasis were not recorded. Cases with mediastinal drainage of any kind and sternal dehiscence were recorded. The patients with positive serologic culture of the mediastinal drainage and sternal dehiscence were accepted as mediastinitis and appropriate treatment (determined by culture antibiogram) was medicated.

Statistical analysis: Statistical analysis was performed with SPSS software version 10.0 (SPSS Inc, Chicago, III). Clinical data were expressed as mean values±standard deviation, percents. Differences between the groups were investigated by Levine test, independent samples t-test and Chi-Square test. We investigated the effects of the variables by calculating odds ratios in univariate analyses for all patients. Both groups and parameters inside each groups were compared using nonparametric Wilcoxon Signed Ranks test (two tailed) was used. Differences were considered as significant when p-value was <0.05.

RESULTS AND DISCUSSION

In present study, 78 males and 56 females, overall 134 patients (mean age 62.2±6.4) were evaluated. The preoperative compared demographic data of the patients were shown in Table 2. The demographic and clinical data of the patients in both groups were similar. Myocardial performance and hemodynamical status were found to be optimal in both groups on based of electrocardiography, echocardiography and cardiac enzyme levels. Postoperative bleeding volume, duration of extubation, follow-up in coronary care unit and hospitalization were lesser in off-pump group compared on-pump group (p<0.05). There was no difference between two group in terms of development of low cardiac output, revision due to bleeding, re-intubation and Intraaortic Balloon Pump (IABP) use. There was also no difference in term of in hospital mortality rate between two groups. Intraoperative and postoperative characteristics of the patients were shown in Table 3.

Two groups were compared in terms of atelectasia and pleural effusion at the 3th and 6th postoperative days. The incidence of atelectasis and pleural effusion was significantly higher in on pump group (p<0.05).

The evaluation of patients according to radiologic signs of chest X-ray was also shown in Table 4. When preoperative and postoperative results of both static and dynamic levels of pulmonary function test owing to expected results as percent were evaluated, statistically significant falls were found in level of all variables as percent while it was much more in on-pump group.

Although, there was no difference in FEV₁ level in preoperative period, it was higher with statistical significance in off-pump group compared on-pump group (77.1±4.2 vs 63.2±4.2, p<0.005, respectively) at postoperative 6th day. FEV₁/VC rate was also higher with statistical significance in off-pump group than on-pump group (88.1±12.1 vs 66.4±14.2, p<0.001, respectively) at postoperative 6th day while there was no difference in preoperative period. The compared function tests were shown in Table 5.

Arteriel blood gasses analysis of both groups is shown in Table 6. In the 1st postoperative day, PaO₂(mm Hg) and O₂ saturation (%) were significantly higher and PaCO₂(mm Hg) was significantly lower in off pump group. Seven patients were reoperated in the first 24 h due to postoperative bleeding (5 in on pump, 2 in off pump).

Overall mortality was 2.98% (2.24% in on pump, 0.74% in off pump). Three patients died in on-pump group in which two deaths has resulted from sepsis due to prolonged mechanical ventilation while the cause of death was severe lifethreatening arrhythmia in one. One patient in off-pump group renal failure due to stroke attack was cause for death.

Table 2: The preoperative demographic data of the patients are shown

Parameters	Total	On-pump	Off-pump	p-value
Patient (number)	134	67	67	
Age (mean±SD)	62.2±6.4	61.8±7.6	62.6±5.2	NS
Male	78	41	37	NS
Female	56	26	30	NS
Ejection fraction (%)	48.4±4.4	49.5±3.2	47.4±2.5	NS
Body mass index (kg m ⁻²)	22.7±1.0	23.4±0.9	22.6±0.3	NS
NYHA (mean)	2.5±0.7	2.4±0.9	2.6±0.6	NS
Diabetes (n)	68	32	34	NS
Smokers (n)	72	35	38	NS
Hypertension (n)	58	26	22	NS
Emergency (n)	9	4	5	NS
Recent myocardial infarction (n)	11	6	5	NS
Left ventricular dysfunction (n)	14	6	8	NS
Chronic renal failure (n)	3	1	2	NS
Peripheral arterial disease (n)	7	3	4	NS
Reoperation (n)	2	1	1	NS
Hematocrit (%)	42.3±3.5	41.4±1.5	43.3±2.6	NS

NYHA: New York Heart Association, NS: Non Spesific

Table 3: The intraoperative and postoperative characteristics paramaters of patients

Factors	On-pump	Off-pump	p-value
Peroperative data			
Left internal mammary artery (n)	52	52	-
Need for inotropic agents (n)	17	14	NS
Sternum and/or fracture of ribs (n)	6	4	NS
Graft (n)	2.9±1.3	2.5±1.2	NS
Cardio bypass (min)	75.5±11.9	-	-
Cross clamp (min)	58.5±9.4	-	-
Postoperative data			
Drainage (mL)	452±70.2	382.5±61.7	<0.05
Mechanical ventilation (h)	14.9±3.69	10.3±2.82	<0.05
Intensive care unit stay (day)	1.9±0.97	1.2±0.63	<0.05
Low cardiac output (n)	3	1	NS
Intraaortic baloon pump usage (n)	3	2	NS
Reentubation (n)	4	2	NS
Stroke	3	1	NS
Hospital stay (day)	11.2±1.6	8.5±1.6	<0.05
Morbidity (n)	17	14	NS
Mortality (n)	3	1	NS

Table 4: Postoperative atelectasis and pleural effusion

Parameters	Atelectasis		Pleural effusion	
	Present (%)	Absent (%)	Present (%)	Absent (%)
Postop. 3rd				
On pump	32 (47.76)	35 (52.24)	16 (23.88)	51 (76.12)
Off pump	18 (26.86)	49 (73.14)	6 (8.95)	61 (91.05)
p-value	<0.05		<0.05	
Postop. 6th				
On pump	19 (28.35)	48 (71.65)	11 (16.41)	56 (83.59)
Off pump	4 (5.92)	63 (94.08)	2 (2.98)	65 (97.02)
p-value	<0.05		<0.05	

The problems related to pulmonary system are the most common cause of mortality and morbidity after CABG surgery. Pulmonary complications during postoperative period may be related to anesthesia, cardiopulmonary by-pass and surgery technique (Royston *et al.*, 1985). It is very important to preserve pulmonary function in patients had deteriorated pulmonary function test and will undergone high risk operations including combination of CABG and heart valves surgery, heart and lung surgery, heart and abdominal surgery or heart and peripheric vessel surgery (Mansuroglu *et al.*,

Table 5: Comparison of preoperative and postoperative function

Factor	Before operation			6 days postoperatively		
	On pump	Off pump	p-value	On pump	Off pump	p-value
FEV ₁ (%)	84.2±6.30	81.6±7.40	0.723	63.2±4.20	77.1±4.20	<0.050
VC (%)	97.1±5.50	98.3±2.40	0.823	70.5±6.20	87.5±5.40	<0.001
FEV ₁ /VC	96.2±10.5	98.2±11.5	0.671	66.4±14.2	88.1±12.1	<0.001

FEV₁: Forced Expiratory Volume in 1 sec, FEV₁/VC: Forced Expiratory Volume in 1 second/Vital Capacity ratio, VC: Vital Capacity

Table 6: Comparison of arterial blood gas measurements preoperatively and in the 1st postoperative day

Parameters	On-pump	Off-pump	p-value
Preop PaO ₂ (mmHg)	78.1±1.20	78.2±5.7	0.672
Postop PaO ₂ (mmHg)	67.1±6.40	76.7±7.3	<0.050
Preop PaCO ₂ (mmHg)	31.1±5.40	31.3±4.2	0.841
Postop PaCO ₂ (mmHg)	38.1±7.30	33.4±4.2	<0.050
Preop O ₂ saturation (%)	99.06±0.2	99.2±1.7	0.912
Postop O ₂ saturation (%)	94.21±3.1	98.5±1.8	<0.050

2004). Many researches have undertaken evaluation to decrease complications related to pulmonary system. It is known well that extracorporeal circulation affects pulmonary functions negatively. CPB disrupts alveolar stability by triggering complement cascade, sequestrating neutrophil in pulmonary microvascular bed providing free radicals release and changing alveolar composition (Hammerschmidt *et al.*, 1981; McGowan *et al.*, 1993). CPB alone is a very important trauma on body.

This is more important in older patients who had vital organ injury. CPB activates systemic inflammatory reactions, damages bleeding-coagulation mechanisms and cardiac arrest during CPB increases likelihood of myocardial injury (Kilger *et al.*, 2001). CBP has been implicated as the major source of alterations in human alveoli structure (Ratliff *et al.*, 1973) in this study. Ratliff reported that cell swellings, interstitial edema and hemorrhage and miliary atelectasis occurred in postcardio period but these changes were not exclusive to patients undergoing CPB.

For instance, in major vascular procedures aortic cross clamping is being implicated as a factor of extravascular lung water accumulation (Klausner *et al.*, 1989). In a recent study comparing early functions after coronary bypass operations in on-pump and off-pump groups, it is mentioned that there was no statistical difference in gas exchange between groups (Kochamba *et al.*, 2000). In a study that 36 patients were enrolled, Cimen *et al.* (2003) found no statistically significant difference in terms of pulmonary function tests, blood gases analysis, extubation duration in early postoperative period.

In some reports it is claimed that early extubation is the consequence of better preservation of respiratory functions (Moshkovitz *et al.*, 1995; Boyd *et al.*, 1999). In several studies, it was reported that there was a decrease in duration of follow-up in coronary care unit and staying at mechanical ventilation in off-pump group compared on-pump group in patients underwent CABG surgery (Kilger *et al.*, 2001). In present study, extubation duration

was lesser and pulmonary function tests were better in off-pump group compared on-pump group (duration: 10.3±2.82 vs. 14.9±3.69; FEV₁/VC: 88.1±12.1 vs. 66.4±14.2, respectively). It was detected that blood transfusion need, follow-up duration in coronary care unit, positive inotropic agent requirement, incidence of neurologic complication, staying at mechanical ventilation duration decreased so, morbidity rate decreased in patients underwent beating heart surgery (Lee *et al.*, 2002; Calafiore *et al.*, 2003; Fanning *et al.*, 1993).

Although, Lee *et al.* (2002) shown that mortality decreased in patients underwent off-pump surgery. Lund *et al.* (2003) found no difference in mortality rate between two groups. In the study mortality and morbidity rates were similar, although follow-up duration in coronary care unit and hospitalization duration were significantly lesser in off-pump group.

In addition we observed that the negative effect of off-pump technique on pulmonary function tests was lesser and blood transfusion need and hospitalization duration were also lesser in off-pump group compared on-pump group. The heart surgery under CPB creates potential sources leading to microembolic results. If ascending aorta is more atherosclerotic, a cannulation with sharp incision may cause significant microemboli. Incomplete (Partial) occlusion clamp can also lead to cerebral microembolization because of it compress aorta mechanically.

In addition, CPB itself may also be a source of microemboli (Kincaid *et al.*, 2000). The risk for cerebral emboli decreases in beating heart surgery because of the manipulations to aorta are lesser but if aorta is often pulled or pushed during surgery, atherosclerotic material can leave from aortic wall and can increase the risk of microemboli even in patients undergoing beating heart surgery (Lund *et al.*, 2003).

In present study, only one patient in off-pump group and just three patients in on-pump group had stroke attack even if CPB and cross clamp causes microemboli leading to neurologic problems but this was not statistically significant.

CONCLUSION

In this study we demonstrated that pulmonary function tests and arterial blood gases were better in

patients underwent CABG surgery without CPB in addition, mortality and morbidity rates were also lesser in this group. Patients going to be surgically revascularized should be altered to without CPB surgery.

The beliefs of improving respiratory functions with off-pump technique. So, it is thought that the off-pump technique is more useful not only in high risk patients but also in all patients will undergo CABG surgery when the negative effect of CPB just on pulmonary function tests is considered.

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