The Cardiology 5 (2): 12-17, 2010
ISSN: 1811-8194


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

Hikmet Iyem
Department of Cardiovascular Surgery, Canakkale Onsekiz Mart University, Canakkale, Turkey

**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 urderwent 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 ($FEV_1$) and $FEV_1$/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 $FEV_1$ 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. $FEV_1$/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 usufel 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 inreased 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 urderwent 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 anomlies 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 ($FEV_1$) and $FEV_1$/VC% of patients in both groups were compared. At each examination in follow-up period, arterial analysis of blood gasses ($PO_2$, $PCO_2$ and $O_2$ 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 institued 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 octobus 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-entubation 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 $FEV_1$ 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. $FEV_1$/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, $PaO_2$ (mm Hg) and $O_2$ saturation (%) were significantly higher and $PaCO_2$ (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 lifethreating 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 myocadial 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 ventitation (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 |
| Reentübation (n) | 4 | 2 | NS |
| Strock | 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 plevral effusion

| | Atelectasis | | Pleural effusion | |
|---|---|---|---|---|
| Parameters | 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 detoriated pulmonary function test and will undergone high risk oparations 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

| | Before operation | | | 6 days postoperatively | | |
|---|---|---|---|---|---|---|
| Factor | 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 |

$FEV_1$: Forced Expiratory Volume in 1 sec, $FEV_1$/VC: Forced Expiratory Volume in 1 second/Vital Capacity ratio, VC: Vital Capacity

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

| Parametrers | 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, sequesrating neutrofil in pulmonary microvascular bad providing free radicals release and changing alveolar composition (Hammerschmidt *et al*., 1981; Mcgowan *et al*., 1993). CPB olone 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 enderwent CABG surgery (Kilger *et al*., 2001). In present study, extubation duration was lesser and pulmonary function tests were beter 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, respestively). 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 urderwent 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 urderwent off-pump surgey. 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 ascendent aorta is more atherosclerotic, a cannulation with sharp incision may cause significant microemboli. Incomplet (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 manupulations to aorta are lesser but if aorta is often pulled or pushed during surgey, atherosclerotic material can leave from aortic wall and can increase the risk of microemboli even in patients urdergoing 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 casues microemboli leaading to neurologic problems but this was not statistically significant.

## CONCLUSION

In this sudy we demonstrated that pulmonary function tests and arterial blood gases were beter 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 usufel 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.

## REFERENCES


Auchinclas, J.H., 1974. Preoperative evaluation of function. Surgical Clinics of North America, 54: 1015-1027.

Ayres, S.M., 1996. Textbook of Critical Care Assessment of Function in Critically Ýll Patient. WB Saunders Company, Philadelphia, PA, USA, pp: 657.

Boyd, W.D, N.D. Desai, D.F. Del Rizzo, R.J. Novick, F.N. McKenzie and A.H. Menkis, 1999. Off-pump surgery decreases postoperative complications and resource utilization in the elderly. Ann. Thorac. Surg., 68: 1490-1493.

Calafiore, A.M., M. Maure, C. Canosa, G. Giammarco, A.L. Iaco and M. Contini, 2003. Early and late outcome of myocardial revascularization with and without cardiopulmonary bypass in high risk patients (EuroSCORE>6). Eur. J. Cardiothorac. Surg., 23: 360-367.

Cimen, S., V. Ozkul, B. Ketenci, N. Yurtsevenb and R. Gunaya *et al*., 2003. Daily comparison of respiratory functions between on-pump and off-pump patients undergoing CABG. Eur. J. Cardiothorac Surg., 23: 589-594.

Cohen, A, M. Katz, R. Katz, E. Hauptman and A. Schachner, 1995. Chronic obstructive pulmonary disease in patients undergoing coronary artery bypass grafting. J. Thorac. Cardiovasc. Surg., 109: 574-581.

Fanning, W.J., G.S. Kakos and T.E. Jr Williams, 1993. Reoperative coronary artery bypass grafting without cardio bypass. Ann. Thorac. Surg., 55: 486-489.

Gass, G.D. and G.N. Olsen, 1986. Preoperative function testing to predict postoperative morbidity and mortality. Chest, 89: 127-135.

Grover, F.L., K.E. Hammermeister and C. Burchfiel, 1990. Initial report of the veterans administration preoperative risk assessment study for cardiac surgery. Ann. Thorac. Surg., 50: 12-26.

Hammerschmidt, D.E., D.F. Stroncek, T.K. Bowers, C.J. Lammi-Keefe and D.M. Kurth, 1981. Complement activation and neutropenia during cardiopulmonary bypass. J. Thorac. Cardiovasc. Surg., 81: 370-377.

Jackson, M.C.V., 1988. Preoperative pulmonary evaluation. Arch. Intern. Med., 148: 2120-2127.

Kilger, E., F.C. Weis, A.E. Goetz, L. Frey and K. Kesel *et al*., 2001. Intensive care after minimally invasive and conventional coronary surgery: A prospective comparison. Intensive Care Med., 27: 534-539.

Kincaid, E.H, T.J. Jones, A.D. Stump, W.R. Brown, D.M. Moody, D.D. Deal and J.W. Jr Hammon, 2000. Processing scavenged blood with a cell saver reduces cerebral lipid microembolization. Ann. Thorac. Surg., 70: 1296-3000.

Klausner, J.M., I.S. Paterson, L. Kobzik, C.R. Valeri, D. Shepro and H.B. Hechtman, 1989. Leukotrienes but not complement mediate limb ischemiainduced lung injury. Ann. Surg., 209: 462-470.

Kochamba, G.S., K.L. Yun, T.A. Pfeffer, C.F. Sintek and S. Khonsari, 2000. Pulmonary abnormalities after coronary arterial bypass grafting operation: Cardiopulmonary bypass versus mechanical stabilization. Ann. Thorac. Surg., 69: 1466-1470.

Lawrence, V.A., C.P. Page and G.D. Harris, 1989. Preoperative spirometry before abdominal operations. a critical appraisal of its predictive value. Arch. Intern. Med., 149: 280-285.

Lee, J.H., M. Capdeville, D. Marsh, K. Abdelhady, A. Poostizadeh and H. Murrell, 2002. Earlier recovery with beating-heart surgery: A comparison of 300 patients undergoing conventional versus off-pump coronary artery bypass graft surgery. J. Cardiothorac. Vasc. Anesth., 16: 139-143.

Lund, C., P.K. Hol, R. Lundblad, E. Fosse and K. Sundet, 2003. Comparison of cerebral embolization during off-pump and onpump coronary artery bypass surgery. Ann. Thorac. Surg., 76: 765-770.

Mansuroglu, D., S.N. Omeroglu, V. Erentug, A. Antal, D. Goksedef, G. Ipek and C. Yakut, 2004. Combined off-pump coronary bypass surgery and abdominal aorta aneurysm repair. J. Card. Surg., 19: 267-269.

Mcgowan Jr, F.X., M. Ikegami, P.J. del Nido, 1993. Cardiopulmonary bypass significantly impairs surfactant activity in children. J. Thorac. Cardiovasc. Surg., 106: 968-977.

Moshkovitz, Y., A. Lusky and R. Mohr, 1995. Coronary artery bypass without cardio bypass: Analysis of short-term and mid-term outcome in 220 patients. J. Thorac. Cardiovasc. Surg., 110: 979-987.

Ratliff, N.B., W.G. Jr Young, D.B. Hackel, E. Mikat and J.W. Wilson, 1973. Pulmonary injury secondary to extracorporeal circulation. J. Thorac. Cardiovasc. Surg., 65: 425-432.

Roques, F., S.A. Nashef, P. Michel, E. Gauducheau and C. de Vincentiis *et al*., 1999. Risk factors and outcome in European cardiac surgery: Analysis of the EuroSCORE multinational database of 19030 patients. Eur. J. Cardiothorac. Surg., 15: 816-822.

Royston, D, B.D. Minty, T.W.Higenbottam, J. Wallwork and G.J. Jones, 1985. The effect of surgery with cardiopulmonary bypass on alveolar-capillary barrier function in human being. Ann. Thorac. Surg., 40: 139-143.

Samuels, L.E., M.S. Kaufman, R.J. Morris, R. Promisloff, S.K. Brockman, 1998. Coronary artery bypass grafting in patients with COPD. Chest, 113: 878-882.

Taggart, D.P., M. Fiky, R. Carter, A. Bowman and D.J. Wheatley, 1993. Respiratory dysfunction after uncomplicated cardiopulmonary bypass. Ann. thorac. Surg., 56: 1123-1128.