Original Article

Effect of Coronary Artery Bypass Grafting Surgery on Pulmonary Function Tests and Arterial Blood Gases

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Abstract

Background and Objective. Pulmonary dysfunction after open heart surgery is an important cause of post-operative morbidity. To evaluate effect of coronary artery bypass grafting (CABG) surgery on pulmonary functions and arterial blood gases (ABGs).

Methods. A prospective study was conducted at a pulmonary unit of a tertiary care public hospital. Of the 50 patients enrolled, 42 patients completed the study. Spirometry was performed one week pre-operatively and within four to five weeks post-operatively. Arterial blood gas samples were also collected just before spirometry. The pre- and post-operative data were compared.

Results. There was significant reduction in forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) by 13.8% and 13.1%, respectively within five weeks of surgery. After surgery mean maximum voluntary ventilation (MVV) showed a significant decrease of 7.6%. Post-operatively, the mean pH decreased significantly by 0.1% and the mean partial pressure of oxygen (PaO_2) and oxygen saturation SpO_2 showed significant decrease of 10.1% and 2.4%, respectively.

Conclusion. Coronary artery bypass grafting has an adverse impact on lung functions and ABGs.
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Key words: Coronary artery bypass grafting surgery, Restrictive lung disease, Pulmonary function test, Arterial blood gases.

Introduction

Pulmonary dysfunction after open heart surgery is a known sequelae and is an important cause of post-operative morbidity. Despite the advances in perfusion and anaesthetic techniques, cardio-pulmonary bypass is still reported to evoke inflammatory reactions that may lead to morbidity, such as bleeding, thromboembolism, fluid retention and pulmonary dysfunction.[1-6] Pulmonary complications in the post-operative period continue to contribute to increased hospital stay and the overall use of resources. The purpose of this study was to examine the changes in the lung functions and arterial blood gases (ABGs) after coronary artery bypass grafting (CABG) surgery. Though information in this area is available in the literature, very little data is there from India.

Material and Methods

Fifty patients with coronary artery disease, who were posted for elective CABG underwent spirometry one week before surgery. Post-operatively, it was repeated within five weeks. Spirometry was performed by trained personnel as per American Thoracic Society (ATS) recommendations. Patients who lost to follow-up in the specified period, those who could not perform spirometry due to post-operative complications, like surgical wound infections, mediastinitis, congestive cardiac failure, patients with extensive structural lung and/or vertebral abnormalities affecting lung functions, and those who died post-operatively were excluded from the study.

Operative Procedure

A midline sternotomy incision was made. The pericardium was opened and potential target vessels were examined and confirmed. Lateral internal mammary artery grafts and saphenous vein conduits were harvested. For on-pump bypass surgery, aorta and right atrium cannulation were performed. The patient was heparinised. A well harvested graft with good flow and size was used as conduit. The patient was put on the cardio-pulmonary bypass machine.

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Anastomosis was achieved between distal (coronary) and proximal (aortic) ends of the graft with 8/0 polypropylene continuous sutures. Heparin reversal was given after confirming hemostasis. Drains were put at appropriate places. Standard chest closure was done using 5-6 steel wires. The patient was shifted to cardiac surgery recovery on cardiac ionotropic drugs and mechanical ventilation. Most patients were weaned-off the ventilator on the first post-operative day and extubated on individual case basis. For off-pump CABG, all the steps were similar, except that the patients were not put on the cardio-pulmonary bypass machine.

Chest Physiotherapy

All patients were subjected to incentive spirometry and deep breathing exercises, pre- and post-operatively. The patients were encouraged to do early ambulation and coughing exercises after surgery. In selected patients, postural drainage was required to drain the respiratory secretions.

Results

Of the 42 patients who completed the study, 22 patients underwent off-pump CABG and 20 patients underwent on-pump CABG. Thirty-five patients were males. The age ranged from 30 years to 70 years. Twenty-four patients (57.1%) had a history of smoking. Four patients (9.5%) had a history suggestive of prior chronic obstructive pulmonary diseases (COPD).

Fifteen (36%) patients had mild left ventricular (LV) dysfunction with LV ejection fraction (LVEF) of more than 55%, 24 (57%) patients had moderate LV dysfunction with LVEF between 30% to 55% and 3 (7%) patients had severe LV dysfunction with LVEF less than 30% in the first post-operative week.

Effects on Spirometry

The spirometric data is shown in table 1. It was observed that the mean FVC (%) showed a mean decrease of 12.4±1.2 ($p<0.001$), i.e. 13.8% after on-pump surgery. In off-pump CABG patients, the mean FVC(%) showed a mean decrease of 12.1±0.8, i.e. 13.4% ($p<0.001$) after surgery.

The mean FEV_1 (%) values in patients with on-pump CABG showed a mean decrease of 12.5±14.3, i.e. 13.1% ($p<0.001$) after surgery, whereas in off-pump patients, the FEV_1 values decreased by 12.5±2.4 ($p<0.001$) after surgery. The mean FEV_1/FVC (%) in on-pump CABG showed non-significant increase of 2.8±10.8, i.e. 3.6% (p=0.07) and similar to that in off-pump CABG 2.8±0.3 (p=0.09). The mean forced expiratory flow ($FEF_{25-75\%}$) in on-pump patients showed a significant decrease of 9.9±23.4 (p=0.043), i.e. 12.4%. In off-pump patients, the mean $FEF_{25-75\%}$ decreased by 9.9±23.4 (p=0.0087) after surgery. The mean MVV (%) showed a significant decrease of 5.2±13.4 (p=0.0158) i.e.7.6% in on-pump and off-pump patients with CABG.

The changes in spirometry parameters in patients undergoing on-pump and off-pump surgery were not statistically significant.

Change in Arterial Blood Gases

The mean pH decreased significantly by 0.1% after surgery (p=0.002). Similarly, the mean PaO_2 and SpO_2 showed significant decrease of 10.1% (p=0.000) and 2.4% (p=0.0000), respectively after surgery (Table 2). The mean PCO_2 and HCO_3 increased by 1.3% and 10.2%, respectively. The differences were not

Table 1. Comparison of change in spirometry parameters between on-pump and off-pump CABG pre- and post-operatively

	FVC		FEV_1		FEV_1/FVC		$FEV_{25-75\%}$		MVV	
	On-pump (n=20)	**Off-pump** (n=22)	**On-pump** (n=20)	**Off-pump** (n=22)	**On-pump** (n=20)	**Off-pump** (n=22)	**On-pump** (n=20)	**Off-pump** (n=22)	**On-pump** (n=20)	**Off-pump** (n=22)
Pre-operatively	90.1±17.2	89.7±16.8	94.8±22.7	94.8±22.7	77.5±11.7	77.5±11.7	79.8±42.8	79.8±42.8	68.2±21.6	68.2±21.6
Post-operatively	77.6±16.0	77.6±16.0	82.4±20.3	82.4±20.3	80.3±12.0	80.3±12.0	69.9±37.5	69.9±37.5	63.0±16.4	63.0±16.4
Change	12.4±1.2*	12.1±0.8*	12.5±2.4**	12.5±2.4**	2.8±0.3^{ns}	2.8±0.3^{ns}	9.9±23.4**	9.9±23.4**	5.2±16.4***	5.2±16.4***
Mean change (%)	13.8	13.4	13.1	13.1	3.6	3.6	12.4	12.4	7.5	7.5

*=$p<0.05$; **=$p<0.001$; ***=$p<0.0001$ and ^{ns}=$p>0.05$

Definition of abbreviations: N=Sample size; CABG=Coronary artery bypass grafting; FVC=Forced vital capacity; FEV_1=Forced expiratory volume in one second; $FEF_{25\%-75\%}$=Forced expiratory flow between 25% and 75% of FVC; MVV=Maximal ventilator volume significant statistically ($p>0.05$). Though there was significant decline in post-operative PaO_2 as compared to the pre-operative PaO_2, there was no difference in the PaO_2 value in the on-pump and off-pump CABG subgroups.

The mean change in ABGs comparing on-pump and off-pump CABG are shown in table 2.

However, they included patients with other cardiac surgeries while we restricted our patients to CABG.

The use of cardio-pulmonary bypass results in activation of alternative complement pathway and release of the anaphylatoxins C3a and C5a that is known to be associated with pulmonary dysfunction.[9] With increase in the alveolar-capillary permeability, cardio-pulmonary bypass leads to shifting of fluid and macromolecules into the pulmonary interstitium and ultimately the alveoli. This may be responsible for different types of pulmonary dysfunction and can progress into acute respiratory distress syndrome.[10]

Table 2. Comparison of change in arterial blood gas parameters between on-pump and off-pump CABG pre- and post-operatively

	pH		PCO_2		PO_2		HCO_3		SpO_2	
	On-pump (n=20)	Off-pump (n=22)	On-pump (n=20)	Off-pump (n=22)	On-pump (n=20)	Off-pump (n=22)	On-pump (n=20)	Off-pump (n=22)	On-pump (n=20)	Off-pump (n=22)
Pre-operatively	7.4±0.1	7.4±0.1	36.7±4.6	36.7±4.6	80.1±7.5	80.1±7.5	24.1±2.2	24.1±2.2	96.3±2.2	96.3±2.2
Post-operatively	7.4±0.1	7.4±0.1	37.1±4.9	37.1±4.9	72.0±8.3	72.0±8.3	24.2±2.2	24.2±2.2	94.0±2.9	94.0±2.9
Change(%)	0.01±0.03*	0.01±0.03*	0.48±3.26^{ns}	0.48±3.26^{ns}	8.12±8.11**	8.12±8.11**	0.06±188^{ns}	0.06±1.88^{ns}	2.34±2.78**	2.34±2.78**

*=$p<0.01$; **=$p<0.001$ and ^{ns}=$p>0.05$

Definition of abbreviations: PCO_2=Partial pressure of carbon dioxide; PO_2=Partial pressure of oxygen; HCO_3=Bicarbonate; SpO_2=Oxygen saturation

Discussion

A number of factors like underlying COPD, obesity, diabetes, advanced age, chronic heart failure, immobility, intra-operative respiratory depression, lung deflation, topical cooling, cardiopulmonary bypass, internal mammary artery dissection, sternotomy, rib fracture, post-operative diaphragmatic dysfunction, pain, atelectasis, impaired blood supply to intercostal muscles, violation of the pleural space, all affect the integrity of the chest and contribute to post-operative pulmonary complications.

Westerdahl *et al*[7] described pulmonary function and pain four months after CABG surgery and observed a significant decrease of 6% to 13% of pre-operative values in FVC, inspiratory capacity, FEV_1, peak expiratory flow rate (PEFR), functional residual capacity (FRC), total lung capacity (TLC) and single-breath carbon monoxide diffusing capacity.

Vargas *et al*[2] studied the influence of atelectasis on pulmonary function after CABG. Six days following CABG, when the post-operative chest radiograph revealed the presence of both atelectasis and pleural changes, the decrease in FVC, FEV_1, TLC, and PaO_2 were significantly greater than when the radiograph was normal.

Shenkman *et al*[8] studied pulmonary functions pre-operatively, 3 weeks and 3.5 months post-operatively in 50 patients undergoing cardiac surgery. Although the timing of spirometry was similar, the decline in lung functions observed in their study was greater in magnitude compared to what we observed.

Pulmonary dysfunction in off-pump group has been attributed to pulmonary congestion resulting from cardiac manipulation, cardiac immobilisation, coronary vessel occlusion, use of internal mammary artery graft, drugs used during the surgery and Trendelenburg position.[11]

Median sternotomy[12] and harvesting of internal mammary artery[13] are two major surgical factors associated with post-operative pulmonary dysfunction. Altered surfactant function due to residual effects of anaesthesia[14] and reduced chest wall compliance and atelectasis[15] are contended as the anaesthetic factors of post-operative pulmonary deterioration that are consistent for all major surgical procedures.

Post-operative pain, retained secretions and especially infections, such as pneumonia have profound impact on pulmonary system. The incidence of pneumonia after CABG is 3% to 16%.[16]

Atelectasis, being implicated as the most important and frequent problem after thoracic surgery, occurs in 73% of patients after internal mammary artery grafting[17] that reduces lung compliance and functional residual capacity. The development of interstitial oedema contributes significantly to the mechanical and gas exchange abnormalities. In major vascular procedures, aortic cross clamping is implicated as a factor of extra vascular lung fluid accumulation.

In our study, in addition to spirometry, we also compared changes in the ABGs pre- and post-operatively. Singh *et al*[18] observed that there was a large decrease in the PaO_2 post-operatively. The *Nadir* for the PaO_2 occurred on the second post-operative day. Eight days post-operatively, there were still significant abnormalities. The decrease in the PaO_2 was particularly noteworthy given the large decrease in the haemoglobin and haematocrit.

In the study by Vargas *et al*[2] the PaO_2 decreased by 12%. However, the decrease in the PaO_2 was greater (approximately 20%) when both atelectasis and pleural changes were present. In comparison, our study had a drop in post-operative PaO_2 of 10.1%.

Previous studies have demonstrated an increase in the alveolar-arterial difference with hypoxemia after cardiac surgery. Both ventilation-perfusion mismatching and right-to-left intra-pulmonary shunting appear to contribute to these changes.

Conclusions

There was a fall in spirometry parameters like FVC, FEV_1, $FEF_{25\text{-}75\,\%}$, MVV with rise in FEV_1/FVC ratio as late as one month after CABG. Restrictive type of spirometry was seen in the one-month post-operative state. There was no significant difference in post-operative spirometry parameters in on-pump and off-pump CABG. There was no difference in the drop in pH and PaO_2, between the on-pump and off-pump CABG patients.

References

1. Conti VR. Pulmonary injury after cardiopulmonary bypass. *Chest* 2001;119:2–4.
2. Vargas FS, Terra-Filho M, Hueb W, Teixeira RL, Cukier A, Light RW. Pulmonary function after coronary artery bypass surgery. *Respir Med* 1997;91:629–33.
3. Guizilini S, Gomes WJ, Faresin SM, Carvalho ACC, Jaramillo JI, Alves FA, *et al*. *Efeitos do local de inserção do dreno pleural nafunçãopulmonar no pós-operatório de cirurgiaderevascularização do miocárdio*. *Rev Bras Cir Cardiovasc* 2004;19:47–54.
4. Taggart DP, el-Fiky M, Carter R, Bowman A, Wheatley DJ. Respiratory dysfunction after uncomplicated cardiopulmonary bypass. *Ann Thorac Surg* 1993;56:1123–8.
5. Wynne R, Botti M. Postoperative pulmonary dysfunction in adults after cardiac surgery with cardiopulmonary bypass: chinical significance and implications for practice. *Am J Crit Care* 2004;13:384–93.
6. Andrejaitiene J, Sirvinskas E, Bolys R. The influence of cardiopulmonary bypass on respiratory dysfunction in early postoperative period. *Medicina* 2004;40 (Suppl. 1):7–12.
7. Westerdahl E, Lindmark B, Almgren S, Tenling A. Chest physiotherapy after coronary artery bypass graft surgery: a comparison of three different deep breathing techniques. *J Rehabil Med* 2001;33:79–84.
8. Shenkman Z, Shir Y, Weiss YG, Bleiberg B, Gross D. The effects of cardiac surgery on early and late pulmonary functions. *Acta Anaesthesiol Scand* 1997;41:1193–9.
9. Kirklin JK, Westaby S, Blackstone EH, Kirklin JW, Chenoweth DE, Pacifico AD. Complement and the damaging effects of cardiopulmonary bypass. *J Thorac Cardiovasc Surg* 1983;86:845–57.
10. Royston D, Minty BD, Higenbottam TW, Wallwork J, Jones GJ. The effect of surgery with cardiopulmonary bypass on alveolar-capillary barrier function in human beings. *Ann Thorac Surg* 1985;40:139–43.
11. Serdar Çimena, Vedat Özkulb, Bülent Ketencia, Nurgül Yurtsevenb, Rafet Günaya, *et al*. Daily comparison of respiratory functions between on-pump and off-pump patients undergoing CABG. *Eur J Cardiothorac Surg* 2003;23:589–94.
12. Berrizbeitia LD, Tessler S, Jacobowitz IJ, Kaplan P, Budzilowicz L, Cunningham JM. Effect of sternotomy and coronary bypass surgery on postoperative pulmonary mechanics: comparison of internal mammary and saphenous vein bypass grafts. *Chest* 1989;96:873–6.
13. Cohen AJ, Moore P, Jones C, Miner TJ, Carter WR, Zurcher RP, *et al*. Effect of internal mammary harvest on postoperative pain and pulmonary function. *Ann ThoracSurg* 1993;56:1107–9.
14. Mathers J, Benumof JL, Wahrenbrock EA. General anesthetics and regional hypoxic pulmonary vasoconstriction. *Anesthesiology* 1077;46:11–14.
15. Egbert LD, Laver MB, Bendixen HH. Intermittent deep breaths and compliance during anesthesiain man. *Anesthesiology* 1963;24:57–60.
16. Jenkins SC, Soutar SA, Loukota JM, Johnson LC, Moxham J. Physiotherapy after coronary artery surgery: are breathing exercises necessary? *Thorax* 1989;44:634–9.
17. Jindani A, Aps C, Neville E, Sonmez B, Tun K, Williams BT, *et al*. Postoperative cardiac surgical care: an alternative approach. *Br Heart J* 1993;69:59–63.
18. Singh NP, Vargas FS, Cukier A, Terra-Filho M, Teixeira LR, Light RW. Arterial blood gases after coronary artery bypass surgery. *Chest* 1992;102:1337–41.