

Long-term pulmonary functional status following coronary artery bypass grafting surgery

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Short Communication

Abstract

BACKGROUND: The present study aimed to describe the long-term alterations of pulmonary function and also to describe its association with post-operative pain after coronary artery bypass grafting (CABG) surgery.

METHODS: In this prospective study, thirty non-smoker male patients undergoing isolated on-pump CABG were consecutively included in this study. Pulmonary function measurements were performed, in a sitting position, preoperatively, a week postoperatively, and 6 months after the surgery using a Medical Graphics PF/Dx pulmonary function system. Pain was determined by using visual analog scale (VAS) pain scores with a standardized questionnaire's.

RESULTS: Regarding functional class, all patients had New York Heart Association (NYHA) Class II to III. A week after operation, a severe restrictive pulmonary impairment was revealed with a mean decrease in VC to $60.9 \pm 9.2\%$ and in forced expiratory volume in one second (FEV₁) to $64.6 \pm 12.2\%$ of pre-operative values ($P < 0.001$). Regarding sternotomy related pain, the mean pain VAS score was preoperatively 3.3 ± 1.5 that reached to 6.2 ± 2.5 and 4.8 ± 2.2 1 week and 6 months after the operation ($P < 0.001$). The trend of the changes in pain score within 6 months of operation was significantly similar to the trend of the changes in some pulmonary function indices such as FEV% and residual volume (RV).

CONCLUSION: A significant reduction is expected in most pulmonary functional parameters following CABG despite normal pulmonary function state preoperatively. Severe pain originated from sternotomy may be an important factor related to pulmonary dysfunction following CABG.

Keywords: Pulmonary Functional, Coronary Artery Bypass Grafting, Post-Operative Pain

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Introduction

The development of pulmonary functional problems such as atelectasis, reduce of oxygenation, and also severe decrease of function parameters such as lung volumes are common findings in patients who undergoing surgical revascularization.^{1,2} The correct etiologies of these pulmonary changes remained questioned, however, seems to be multifactorial probably related to anesthesia reactions, diaphragmatic dysfunction, sensitivity to medications, changes in hemodynamic parameters, intra-operative events, and post-operative pain.³⁻⁶ The decrease in pulmonary function was firstly described that suggested as the consequences of post-operative pain rose from

sternotomy.⁷⁻⁹ Thereafter, various studies focused the main reasons for appearing pulmonary dysfunction. Some could show significantly reducing dynamic lung volumes and also expiratory flow rates occurred early after coronary revascularization; while pulmonary dysfunction has been also reported long-term after this procedure in a few studies.^{10,11} Moreover, there are a few published evidences on the long-term alterations of pulmonary function following coronary artery bypass grafting (CABG) surgery.^{12,13} Hence, the present study aimed to describe the long-term alterations of pulmonary function and also to describe its association with post-operative pain after CABG surgery.

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Materials and Methods

Study design and participants: In this prospective study, 30 nonsmoker male patients undergoing isolated on-pump CABG were consecutively included in the study. Those who had unstable angina, previous cardiac surgery or severe renal dysfunction were excluded. Informed consent was obtained from each participant and Ethical Committee of Shahrekord University, Iran, approved the study.

Operation was conducted on general anesthesia with the same anesthesia protocols for all with cardiopulmonary bypass through a median sternotomy. Postoperatively, the patients were ventilated with a positive end-expiratory pressure of 5 cm H₂O and an inspired oxygen concentration of 60 to 80%. After extubation, all subjects received pain relief with morphine and paracetamol according to their needs along with routine post-operative protocol. The patients also received basic post-operative care as conventionally used at our hospital. Pain was measured by an 11-point pain scale (0, no pain, 10, maximal imaginable pain).¹² Pulmonary function tests were performed in the usual manner on PODs 7 and 14 by portable spirometer (Autospiro AS-303, Minato Medical Science Co Ltd., Osaka, Japan). Recovery rates of forced vital capacity (FVC), vital capacity (VC), and forced expiratory volume in one second (FEV1) were expressed by the percent of predicted values that were calculated by numbers of resected pulmonary segments:

Predicted value (ml) = pre-operative value (ml) * (19-the number of resected segment)/19

Pulmonary function measurements were performed, in a sitting position, preoperatively, a week postoperatively, and 6 months after the surgery using a Medical Graphics PF/Dx Pulmonary Function System. In this regard, the highest value of two or three technically satisfactory maneuvers was retained for measurement of VC, inspiratory capacity (IC), FEV1 and peak expiratory flow rate (PEFR). FEV% was calculated as FEV1 in percentage of VC. Functional residual capacity (FRC) and residual volume (RV) were measured with the single-breath nitrogen washout technique. Total lung capacity (TLC) was also calculated as VC + RV. The single-breath carbon monoxide diffusing capacity (DLCO) was measured according to the method previously described.¹⁴ The DLCO values were corrected using the standard equation on hemoglobin concentration.¹⁵ On above three-time points of surgery, sternotomy wound pain was also quantified at rest using a continuous unmarked visual analog scale (VAS) ranged from 0 (no pain)

to 10 (worst imaginable pain).

Statistical analysis: Results were presented as mean \pm standard deviation for quantitative variables and were summarized by absolute frequencies and percentages for categorical variables. The one-way repeated-measures ANOVA and post-hoc Bonferroni test were used. For the statistical analysis, the statistical software SPSS for Windows (version 20, SPSS Inc., Chicago, IL, USA) was used. P = 0.05 or less were considered statistically significant.

Results

The average age of the patients was 67.75 ± 10.25 years, and the mean body mass index was 25.58 ± 4.41 kg/m². Regarding functional class, all patients had New York Heart Association (NYHA) class II to III. Furthermore, mean left ventricular ejection fraction was $61.95 \pm 12.22\%$. Before surgery, all patients had normal lung function related to the reference values of VC as $92.6 \pm 13.4\%$ of predicted and FEV1 as $98.8 \pm 20.4\%$ of predicted. A week after operation, a severe restrictive pulmonary impairment was revealed with a mean decrease in VC to $60.9 \pm 9.2\%$ and in FEV1 to $64.6 \pm 12.2\%$ of pre-operative values (P < 0.001). Six month after surgery, reduction in some parameters including PEFR, FRC, TLC and DLCO were still found compared to pre-operative values (P < 0.001), whereas no significant abnormality was shown in FEV, RV and DLCO/VA (P = 0.543, P = 0.765 and P = 0.064, respectively) as shown in table 1. Regarding sternotomy related pain, the mean pain VAS score was preoperatively 3.3 ± 1.5 that reached to 6.2 ± 2.5 and 4.8 ± 2.2 1 week and 6 months after operation. The trend of the changes in pain score within 6 months of operation was significantly similar to the trend of the changes in some pulmonary function indices such as FEV% and RV.

Discussion

Our study could show a significant reduce in most pulmonary functional parameters following CABG despite normal pulmonary function state preoperatively. Also, to determine the association between sternotomy related pain score and changes in these parameters, we could show a similarity between the trends of the changes in some pulmonary function indices and pain score following CABG. On the other hand, pulmonary function state can be potentially affected by post-sternotomy pain severity. Of course, post-operative pain is not only predictor for post-operative pulmonary dysfunction. In some previous studies,

Table 1. Pulmonary function and pulmonary diffusing capacity data preoperatively, on the 7th post-operative day and 6 months after coronary artery bypass grafting (CABG)

	Pre-operative	1 week after	6 months after	P
VC	64.1 ± 0.4	60.9 ± 9.2*	61.4 ± 0.6*	
IC	3.7 ± 0.2	2.2 ± 0.1*	2.2 ± 0.3*	< 0.001
FEV1	73.4 ± 0.5	64.6 ± 12.2*	68.4 ± 0.2*	
FEV	74.4 ± 8.2	78.2 ± 8.9	72.2 ± 7.8	0.543
PEFR	557.3 ± 125.1	354.7 ± 118.9*	477.2 ± 127.5*	< 0.001
FRC	3.3 ± 0.6	2.2 ± 0.7*	2.8 ± 0.5*	0.020
RV	2.2 ± 0.6	1.7 ± 0.4	2.0 ± 0.6	0.765
TLC	6.6 ± 0.2	4.4 ± 0.5*	5.8 ± 0.3*	
DLCO	23.3 ± 5.8	15.5 ± 3.1*	22.5 ± 5.5*	< 0.001
DLCO/VA	3.3 ± 0.6	3.8 ± 0.8	3.8 ± 0.7	0.064
VAS score	3.3 ± 1.5	6.2 ± 2.5*	4.8 ± 2.2*	< 0.001

* Significant P value obtained by Tukey Post hoc; VC: Vital capacity; IC: Inspiratory capacity; FEV1: Forced expiratory volume in one second; PEER: Peak expiratory flow rate; FRC: Functional residual capacity; RV: Residual volume; TLC: Total lung capacity; DLCO: Single-breath carbon monoxide diffusing capacity; VAS: Visual analogue scale

aging has been also shown as a strong predictor for pulmonary dysfunction after major surgeries. It has been demonstrated that a decrease in pulmonary function is to be expected for reasons of ageing in longtime after surgery. According to reference values,^{16,17} the normal reduction is for VC and FEV1 about 20-30 and for FRC 10 ml per year in nonsmokers. Also, the type of arteries or veins used as grafts may also be another determinant for deterioration of pulmonary functional state as previously by Vargas et al.² study. In their study, on the first post-operative day, the FVC decreased to 33% of the pre-operative value in the saphenous vein graft group and to 29% in the internal mammary artery group. The spirometry gradually improved, but after 10 days, the FVC remained reduced. Although the decreases in FVC tended to be greater in the internal mammary artery group, there was no significant difference in the two groups. The changes in FVC were not significantly related to age, smoking history, anesthesia or pump time. In another study by Westerdahl et al.,¹⁸ 4 months postoperatively, the patients still showed a significant decrease (6-13% of pre-operative values) in VC, IC, FEV1, peak expiratory flow rate (PEER), FRC, TLC, and DLCO. RV and DLCO per litre of alveolar volume had returned to the pre-operative level. Four months postoperatively, the median values for sternotomy pain while taking a deep breath was 0.2 and while coughing 0.3 on a 10 cm visual analogue pain scale. In another study by Ergun and Sirlak¹⁹ in the results the post-operative PFT values were significantly decreased. However, the RV, RV% and RV/TLC values were not changed significantly. In the investigation by Shenkman et al.,¹¹ a more pronounced decrease in pulmonary

function is described after cardiac surgery. No static lung volumes or dilution capacity were measured, but the FVC was reduced by an average of 25% in FEV1 and PEFR 3-4 months after surgery. FEF50, FEF75 and maximal voluntary ventilation did not recover at all 3.5 months postoperatively compared to 3 weeks after surgery. This indicates that pulmonary function after cardiac surgery is long lasting, and may even be permanent.

Many factors that may have an influence on the impairment have been suggested. Altered mechanics after opening of the thorax, reduced rib cage expansion and uncoordinated chest wall motion may possibly persist for several months. Both respiratory muscle weakness and alterations in chest wall mechanics induced by surgery may contribute to these changes.^{9,20} Basal atelectasis develops early during anesthesia and possibly will persist into the post-operative period.²¹ We could show that severe pain originated from sternotomy may be an important factor related to pulmonary dysfunction following CABG beside other factors related to the chest wall deformation or pulmonic dynamic changes.

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Conflict of Interests

Authors have no conflict of interests.

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