Cardiovasc Surg Int 2020;7(2):63-69
http://dx.doi.org/DOI: 10.5606/e-cvsi.2020.847
www.e-cvsi.org

Original Article Open Access

Does pleurotomy have any effect on postoperative respiratory system functions after cardiac surgery?

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Received: June 02, 2020 ***Accepted:*** June 22, 2020 ***Published online:*** July 28, 2020

ABSTRACT

Objectives: The aim of this study was to evaluate the effects of pleural integrity on respiratory system functions after cardiac surgery.

Patients and methods: In this prospective, cohort study, a total of 114 patients (84 males, 30 females; mean age 56.3±13.1 years; range, 21 to 76 years) who underwent on-pump cardiac surgery between February 2016 and June 2016 were included. The patients were divided into two groups: open (Group 1, n=56) and intact pleura (Group 2, n=58). Arterial blood gas values (pH, partial pressure of oxygen [PaO_2], partial pressure of carbon dioxide [$PaCO_2$], and oxygen saturation [SaO_2]), and respiratory and heart rates were evaluated per-operatively. Preoperative and the fifth postoperative day values of forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and FEV1/FVC% were compared between the groups.

Results: Extubation time and duration of mechanical ventilation were similar in both groups ($p>0.05$). There was a significant decrease of FEV1 and FVC of open versus intact pleura group in terms of preoperative and the fifth postoperative day values ($p<0.001$ and $p<0.001$, respectively). There was no significant difference in the $PaCO_2$ in arterial blood gas between the groups (open; 38.6±3.5 vs. 39.0±4.2 mmHg, Intact; 37.8±2.3 vs. 38.1±2.1 mmHg, respectively p=0.49) at room air before surgery and on the first postoperative day ($p>0.05$). However, a significant decrease was observed in the PaO_2 (p=0.006 vs. $p<0.001$, respectively) and SpO_2 ($p<0.001$ vs. $p<0.001$, respectively) values of the groups between the preoperative and the fifth postoperative day values. The only significant difference regarding postoperative complications, which was higher in Group 1 (p=0.003), was observed in bleeding on the first postoperative day.

Conclusion: Based on our study findings, opened pleura seems not to be associated with a higher incidence of pulmonary complications, compared to the intact pleura.

Keywords: Blood gas analysis, cardiac surgical procedures, pleural effusion, respiratory insufficiency.

The causes of postoperative respiratory complications depend on several factors during cardiac surgery, and the underlying pathophysiological mechanisms include adverse effects of general anesthesia, mechanical ventilation, atelectasis, systemic inflammatory response related to cardiopulmonary bypass (CPB) procedure and various surgical techniques which may lead to deterioration in the respiratory functions.[1-5]

Previous studies have shown that possible opening of the pleura during internal mammary artery (IMA) harvesting may cause respiratory dysfunction after coronary artery bypass grafting (CABG).[1,2] On the contrary, few researches have demonstrated that preservation of the pleural integrity during IMA harvesting significantly reduces postoperative bleeding without affecting pulmonary functions.[6-8] Although limited, there are studies investigating the effect of pleural integrity in patients undergoing isolated valve operations or both valve and CABG operations.[9-11] In the present study, we aimed to evaluate the effects of pleural integrity on respiratory system functions and complications after cardiac surgery.

PATIENTS AND METHODS

In this prospective, cohort study, a total of 114 patients (84 males, 30 females; mean age 56.3±13.1

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Citation:
Altaş Ö, Yerlikhan O, Aksüt M, Özer T, Çakalağaoğlu C, Köksal C. Does pleurotomy have any effect on postoperative respiratory system functions after cardiac surgery? Cardiovasc Surg Int 2020;7(2):63-69.

years; range, 21 to 76 years) who underwent on-pump cardiac surgery between February 2016 and June 2016 were included. The patients were divided into two groups depending on whether the pleura was opened or intact during the surgical procedure as Group 1 (n=56, 49.1%) with an opened pleura and Group 2 (n=58, 50.9%) with an intact pleura. The preoperative and the first postoperative week data were recorded. The parameters of the study included chest X-rays, and spirometric respiratory functional tests, and arterial blood gas analysis. A written informed consent was obtained from each patient. This study was approved by the Institute Research Medical Ethics Committee at Kosuyolu Heart Training and Research Hospital. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Arterial blood gas analysis (pH, partial arterial oxygen pressure [PaO_2], partial arterial carbon dioxide pressure [$PaCO_2$], and arterial oxygen saturation [SpO_2]), heart rate and respiratory rate were evaluated preoperatively and within 8 h after extubation on the first postoperative day. Spirometric studies (forced expiratory volume in one second [FEV1]%, forced vital capacity [FVC]%, and FEV1/FVC%) were conducted preoperatively and on the fifth postoperative day.

Patients with prior cardiac surgery, emergency surgery, reduced lung function test, abnormal clotting parameters or coagulation disorders, pleural adhesions, reduced left ventricular ejection fraction (<30%), degenerative alterations of the vertebral column, or psychiatric disturbances were excluded. In our institute, preserving pleural integrity is primarily aimed in patients undergoing median sternotomy. According to the American Thoracic Society/ European Respiratory Society (ATS/ERS) Position Statement on the diagnosis and treatment of chronic obstructive pulmonary disease (COPD), patients with mild-to-moderate COPD with FEV1 ≥50% and FEV1/FVC ≤0.7 were not included in the study.[12]

Pleural effusion was considered relevant, when it was moderate (pleural effusions represented a significant accumulation of pleural fluid, but did not produce respiratory symptoms and did not require thoracentesis) or large (pleural fluid which resulted in dyspnea and required thoracentesis), while atelectasis was considered significant when a clear radiological shadow with a width more than 15 mm was observed on chest X-ray. The anteroposterior chest X-rays were taken 24 h after extubation and, if possible, on the sixth postoperative day or before discharge.[13] Chest X-rays were interpreted by a single radiologist and the spirometric studies and arterial blood gases were interpreted by a single anesthesiologist who were both blinded to the study groups. Median sternotomy was performed in all patients. Intermittent inflation of the lungs was the ventilator management strategy during CPB. The remaining steps were carried out in a standard fashion.

Chest tube drainage was documented for 24 h postoperatively. Chest tubes were removed, when drainage was less than 100 mL/day. Acetylsalicylic acid (150 mg/day) was given on the first postoperative day, and sodium warfarin was additionally used for patients who underwent valvular operations. Reoperation for bleeding was defined as bleeding which required early surgical re-exploration after the end of the operation. The criteria were as follows: the drainage of more than 500 mL of blood during the first 1 h, more than 400 mL during each of the first 2 h, more than 300 mL during each of the first 3 h or more than 1,000 mL in total in the first 4 h; sudden massive bleeding; obvious signs of cardiac tamponade; and excessive bleeding despite correction of coagulopathies.[14] All patients were transferred to the intensive care unit (ICU) after the operation. The lungs were initially ventilated in synchronized intermittent mandatory ventilation at 12 to 14 breaths/min, an inspiratory/ expiratory ratio of 1:2, positive end-expiratory pressure (PEEP) of 3 cmH_2O, and tidal volume of 8 mL/kg of body weight for keeping arterial oxygen saturation above 90%. All patients received similar analgesic protocol administered during the initial five postoperative days and were given daily chest physiotherapy until discharge. If an acute respiratory insufficiency episode was diagnosed with regard to criteria for acute respiratory distress (dyspnea, respiratory rate more than 24 breaths/min, use of accessory muscles of respiration, arterial blood gas analysis with pH<7.35 and partial pressure of oxygen in arterial blood PaO_2/fraction of inspired oxygen (FiO_2) ratio less than 200 mmHg or PaO_2 less than 60 mmHg, while the patient was breathing oxygen through an air-entrainment mask), patients received bilevel positive airway pressure (BiPAP) in addition to standard therapy.[13] Standard treatment included diuretics, inhaled beta-agonist, and inhaled ipratropium bromide, and intravenous theophylline, if clinically indicated.

On the second postoperative day, all catheters, urinary catheters, and central venous and arterial lines were removed and the patients were mobilized as soon as possible. The hospital mortality was defined as death for any reason occurring within 30 days after the operation.[15] Respiratory failure was defined as pulmonary insufficiency requiring intubation and ventilation for a period of 72 h or longer at any time during the postoperative stay. Low cardiac output syndrome was defined as a cardiac index of 2.0 L/min/m^2, requiring pharmacological support of more than one inotropic agent and/or use of intra-aortic balloon pump.[16] Postoperative renal dysfunction was defined as an increment in the creatinine level of ≥1 mg/dL compared to the preoperative value. Neurological complications as any focal brain lesion were confirmed based on clinical findings or cranial computed tomography imaging.[17] The critical hematocrit value is patient- and organ-specific and varies intraoperatively according to the duration and temperature of bypass, as well as for a variable postoperative period.[18]

Statistical analysis

Statistical analysis was performed using the Number Cruncher Statistical System (NCSS) version 23 (NCSS LLC, Kaysville, Utah, USA) & and Power Analysis and Sample Size (PASS) version 23 (NCSS LLC, Kaysville, Utah, USA) statistical software. Normal distribution was evaluated using the Kolmogorov-Smirnov test. Descriptive data were presented in mean ± standard deviation (SD), median (min-max) or number and frequency. Categorical variables between the groups were compared using the Student t-test, while the paired sample t-test and Wilcoxon signed-rank test were used to evaluate normally and non-normally distributed variables, respectively. Roentgenographic data were analyzed using the Fisher's exact test. Qualitative data was compared using the chi-square and Fisher's exact test, when appropriate. A p value of <0.05 was considered statistically significant.

RESULTS

There was no significant difference in the demographic characteristics, pre- and intraoperative

Table 1
Demographic characteristics and perioperative data

	Total (n=114)			Opened pleurae (Group 1; n=56)			Intact pleurae (Group 2; n=58)			
Variables	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			56.3±13.1			58.1±11.7			54.6±14.3	0.15
Body surface area (m^2)			1.8±0.2			1.8±0.2			1.7±0.2	0.14
Men (%)		73.7			75			72.4		0.75
Smoking history (%)		42.1			39.3			44.8		0.55
Ejection fraction (%)			57.6±8.2			56.2±9.3			59±6.7	0.07
EuroSCORE			2.7±2.1			2.7±2.4			2.6±1.7	0.58
Hematocrit (preoperative) (%)			43.3±3.5			44.3±3.6			42.6±3.5	0.69
CC time (min)			59.7±32.8			57.8±27.4			61.5±37.4	0.55
CPB time (min)			92.8±34.5			93.7±30.4			91.8±38.2	0.77
Isolated CABG	83			44			39			0.33
Combined CABG and valve surgery	6			2			4			0.21
Valve surgery	25			10			15			0.19
Distal anastomoses, (number of vessels)			2.6±0.7			2.7±0.7			2.5±0.8	0.27
LIMA		95.4			95.8			95		0.98

SD: Standard deviation; CC: Cross-clamp; CPB: Cardiopulmonary bypass; CABG: Coronary artery bypass grafting; LIMA: Left internal mammary artery.

Table 2
Pre- and postoperative spirometric respiratory function test results after extubation

	Opened pleurae (n=56)	Intact pleurae (n=58)	
	Mean±SD	Mean±SD	*p**†
FEV1 (%)			
Preoperative	92.3±25.0	88.9±16.4	0.55
Postoperative	59.3±18.6	63.7±14.7	0.09
p‡	0.001*	0.001*	
FVC			
Preoperative	90.3±18.7	89.1±16.3	0.7
Postoperative	57.9±19.1	64.2±13.9	0.07
p‡	0.001*	0.001*	
FEV1/FVC (%)			
Preoperative	104.4±14.2	103.4±12.5	0.69
Postoperative	104.1±12.3	101.7±9.2	0.23
p‡	0.88	0.38	

SD: Standard deviation; FEV1: Forced expiratory volume in one second; FVC%: Forced vital capacity (FVC%); * p<0.05; † Student t-test; ‡ Paired sample t-test.

data of the patients including type of operations, EuroSCORE, and ejection fraction between the groups. A total of 72.8% of the patients underwent CABG, while 22% had valve surgery. Medications of pulmonary and cardiac systems prior to operation were similar (p>0.05) (Table 1).

Comparison of pre- and postoperative (Day 5) spirometric values showed no significant difference between the groups in terms of FEV1, FEV1(%), FVC, and FEV1/FVC (p>0.05). However, there was a significant decrease in the FEV1(%) and FVC of both groups on the fifth postoperative day compared to the preoperative values (p<0.001 and p<0.001, respectively). Pre- and postoperative FEV1/FVC ratios of the groups were similar (p>0.05) (Table 2).

A comparison of clinical data and arterial blood gas parameters are presented in Table 3. There were no significant differences between the two groups with respect to the respiratory rate, heart rate, arterial blood gas values at room air such as pH, PaO_2, $PaCO_2$, and SpO_2, comparing the preoperative period through the first postoperative day (p>0.05). However, there were significant differences in the PaO_2 and SpO_2 levels comparing the preoperative and post-extubation period between Group 1 and Group 2 (p<0.05).

In addition, there was no significant difference in the perioperative incidence of atelectasis or pleural effusions. However, atelectasis in each group increased significantly 24 h after extubation (p<0.05). Also, atelectasis at 72 h after extubation showed a significant difference compared to preoperative values (p<0.05); however, no significant change was observed on chest X-ray between the two groups (p>0.05). Pleural effusion significantly increased on the third postoperative day compared to preoperative in both groups (p=0.01 and p=0.001, respectively), although

Table 3
Respiratory rate, heart rate, and arterial blood gases preoperatively and on the first postoperative day

	Opened pleurae (n=56)			Intact pleurae (n=58)		
	Before operation	After operation on day 1		Before operation	After operation on day 1	
Parameters	Mean±SD	Mean±SD	*p*	Mean±SD	Mean±SD	*p*
RR (rate/min)	23.0±1.3	24.5±3.2	0.09	24.9±2.3	26.8±2.6	0.21
HR (rate/min)	106.8±14.6	108.3±11.6	0.43	104.4±13.3	105.6±10.6	0.48
Ph	7.36±0.0	7.36±0.0	0.33	7.4±0.0	7.4±0.0	0.5
PaO_2 (mmHg)	86.2±7.5	82.6±10.2	**0.006***	85.6±7.04	80.2±11	**<0.001***
$PaCO_2$ (mmHg)	38.6±3.5	39.0±4.2	0.49	37.8±2.3	38.1±2.1	0.49
SpO_2 (%)	95.9±1.8	93.9±2.4	**<0.001***	96±1.4	93.9±2.5	**<0.001***

SD: Standard deviation; RR: Respiratory rate (breaths/min); HR: Heart rate (bpm); PaO_2: Partial pressure of arterial oxygen; $PaCO_2$: Partial pressure of arterial carbon dioxide; SpO_2: Oxygen saturation; * p<0.05.

Table 4
Postoperative respiratory system-related complications

	Opened pleurae (n=56)		Intact pleurae (n=58)		
	n	%	n	%	*p*
Reentubation†	2	3.6	2	3.4	0.97
Atelectasis‡					
Preoperation	0	0	0	0	1
Postextubation (24 h)	12	21.4	10	17.2	0.57
Postextubation (72 h)	16	28.6	17	29.3	0.93
p§	**0.01***		**0.007***		
Pleural effusion‡					
Preoperation	2	3.6	2	3.4	0.57
Postextubation (24 h)	4	7.1	3	5.1	0.73
Postextubation (72 h)	15	26.7	9	15.5	0.2
p§	**0.001***		**0.01***		
Bilevel positive airway pressure‡	16	28.6	10	17.2	0.15

SD: Standard deviation; † Fisher's exact test; ‡ Chi-square test; § Wilcoxon signed-rank test; * p<0.05.

there was no significant change between the two groups (p>0.05) (Table 4). Comparison of respiratory complications in the ICU revealed that there were no significant differences between the groups in terms of the reintubation, atelectasis, or pleural effusion and patients requiring BiPAP treatment (p>0.05) (Table 4). The extubation time and duration of mechanical ventilation were similar in both groups (p>0.05) (Table 5). There were no signs of perioperative myocardial infarction in either group.

There was significant difference only in the postoperative bleeding of the first postoperative day between the two groups. The mean amount of bleeding was higher in Group 1 (612.5±274.2 mL) compared to Group 2 (481.0±182.2 mL) (p=0.003) (Table 5). No significant difference was observed in the rate of arrythmias, low cardiac output syndrome, and renal dysfunction (p>0.05). None of the patients had sternal infection, mediastinitis, sternal dehiscence, or neurological or gastrointestinal complications. In addition, there were no cases of 30-day mortality in two groups. The length of ICU and hospital stay was similar between the two groups (p>0.05).

Table 5
Postoperative data of the patients

	Total (n=114)			Opened pleurae (n=56)			Intact pleurae (n=58)			
Parameter	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Bleeding (mL/24 h)†			545.6±240.2			612.5±274.2			481.0±182.2	**0.003***
Ventilation time (h)‡			11.4±4.4			11.1±4.7			11.7±4.2	0.39
ICU stay time (days)‡			2.9±2.7			3.0±1.8			2.6±1.2	0.26
Hospital stay time (days)‡			9.3±3.0			9.7±3.4			8.9±2.5	0.20
LCOS§	4	3.4		2	3.6		2	3.4		0.57
Renal dysfunction¶	4	3.5		2	3.6		2	3.4		1.00
Mortality	0	0		0	0		0	0		1.00

SD: Standard deviation; ICU: Intensive care unit; LCOS: Low cardiac output syndrome; * p<0.05; † Student t-test; ‡ Mann-Whitney U test; § Chi-square test; ¶ Fisher's Exact test.

DISCUSSION

Although we aim to preserve pleural integrity during cardiac surgery in our institution, some surgeons perform routine pleurotomy prior to IMA harvesting to expose and prevent tension. This approach led us to constitute this study. Altered respiratory system functions are frequently observed after cardiac surgery. Reduced FVC and arterial oxygen tension are found to be responsible for the changes in the lung functions and are related to increased morbidity and mortality in the early postoperative period.[1,18] The effect of pleurotomy on pulmonary function can be explained by a higher incidence of pleural effusion and atelectasis, increased intrapulmonary shunting, and postoperative pleuritic chest pain.[6] However, some studies showed that restrictive defect in pulmonary function observed during the first 72 h after cardiac operations with CPB was unaffected by the interference with the pleural integrity.[11,19,20] Another important finding in our study is that FEVI/FVC values on the fifth postoperative day did not significantly differ from preoperative values, indicating a lack of significant pulmonary obstruction (Table 2). All patients received chest physiotherapy, as well as early mobilization, to prevent retention of secretions to be a source of decrease in the functional residual capacity (FRC) or atelectasis.[21] In the evaluation of arterial blood gas values, some authors reported a negative influence of pleurotomy in the PaO_2 and PaO_2/FiO_2 during on-pump CABG with the use of the left internal mammary artery (LIMA).[16,17] Unlike many other studies, decrease in the PaO_2 occurred in both groups on the first postoperative day and the decrease within the groups did not significantly differ ($p>0.05$) (Table 3).

In a meta-analysis of 19 randomized-controlled studies comparing IMA harvesting with intact versus open pleura, all patients demonstrated significant deterioration in the pulmonary function tests and radiographic appearance postoperatively.[20] Although pleurotomy seemed to have increased rates of atelectasis and effusions, the study showed no impact on clinical outcomes and length of hospital stay. As in our study, we found no impact on the postoperative outcomes. In contrast to these findings, decrease in the lung volume, as well as FRC, atelectasis and postoperative reduction of the PaO_2 were similar. We observed no complications directly related to pleurotomy. Many studies showed that the incidence of atelectasis was limited in preserved pleural integrity,[20,21] although there was no significant difference in the atelectasis rate of our patient groups. We believe that it could be due to pain-related breath restriction and mucus retention, leading to atelectasis. Unlike most published researches, we believe that pleurotomy reduces some adverse effects, such as tamponade or pneumothorax, in the early postoperative period. Another issue related to oxygenation is the placement of pleural drainage tube or thoracostomy tube and it has been shown that such a procedure is associated with decreased oxygenation secondary to chest wall pain, splinting, and reluctance of the patient to cough, sigh, and taking deep breaths.[21] Some authors reported that pleural effusion was more common following the LIMA harvesting.[4] Other studies, unlikely, found that pleural effusion occurred with the same frequency after CABG, even in the absence of the LIMA harvesting.[22] However, Labidi et al.[23] reported 11.9% incidence of symptomatic pleural effusion in their prospective study. We showed that the pleural integrity has no effect on pleural effusions (Table 4). Both groups of this study consisted of patients undergoing IMA harvesting, as well as valve surgery. This result has been also supported by findings of Iskesen et al.[8] showing that preservation of the pleural integrity during LIMA harvesting did not have any effect on atelectasis or pleural effusions. Lim et al.[9] divided 206 patients into three groups: isolated CABG patients (n=138), valve surgery patients (n=39), and combined procedure patients (n=29). Although patients with a left pleurotomy (n=164) had a higher incidence of left lung atelectasis (67.7% vs. 45.2%, respectively; p=0.007), there was no significant difference in pleural effusion (42.5% vs. 46.3%, respectively; p=0.66) and these results were not associated with an adverse clinical outcome.

It is crucial that postoperative bleeding, which was fewer with the preserved pleural integrity (p=0.003) in our study, has been shown in many studies.[7,8] Excessive bleeding in our opened pleurotomy group did not cause any pulmonary complications. Besides, postoperative anticoagulation in valve operations may increase the risk for cardiac tamponade, and pleurotomy may act as a safeguard against such a complication. This study found no significant association between bleeding and cardiac tamponade. We excluded patients with previous lung disease, such as chronic obstructive pulmonary disease, to prevent possible source for a higher incidence of respiratory related complications.

Nonetheless, there are some limitations to our study that we were unable to measure postoperative long-term respiratory tests to detect changes over time. On a chest X-ray, it can be difficult to identify atelectasis visually. However, uniform analysis was used to avoid bias of data evaluation.

In conclusion, our study results suggest that opened pleura seems not to be associated with a higher incidence of pulmonary complications, compared to the intact pleura. However, further large-scale, prospective studies are needed to establish a definitive conclusion.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

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