Sub-xyphoid pleural drain as a determinant of functional capacity and clinical results after off-pump coronary artery bypass surgery: a randomized clinical trial

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Abstract

OBJECTIVES: The aim of this trial was to compare functional capacity, pulmonary shunt fraction and clinical outcomes between patients undergoing pleurotomy with a pleural drain inserted in the sub-xyphoid position and patients with a pleural drain placed in the intercostal position after off-pump coronary artery bypass surgery.

METHODS: Patients were randomized into two groups according to the pleural drain site: Group II (n = 33 intercostal pleural drain); and Group SI (n = 35 sub-xyphoid pleural drain). Functional capacity was assessed by the distance covered on the 6-min walking test performed preoperatively and on postoperative day (POD) 5; in addition, pulmonary function test was determined preoperatively and on POD 1 and 5. Pulmonary shunt fraction was evaluated preoperatively and on POD 1, and clinical outcomes were recorded throughout the study.

RESULTS: Group SI had better preservation of lung volumes and capacities in POD compared with Group II (P <0.05). Pulmonary shunt fraction increased in both groups postoperatively; however, Group SI showed a smaller pulmonary shunt fraction (0.26 ± 0.04 vs 0.21 ± 0.04%; P = 0.0014). Functional capacity was significantly reduced in both groups on POD 5; however, Group SI showed better preservation of functional capacity (P = 0.0001). Group SI had better postoperative clinical results, with lower incidence of atelectasis and pleural effusion (P <0.05), lower pain scores (P <0.0001), and shorter orotracheal intubation and hospitalization lengths (P <0.001).

CONCLUSIONS: Sub-xyphoid pleural drain determined better functional capacity and exercise tolerance with a smaller pulmonary shunt fraction and improved clinical outcomes compared with intercostal pleural drainage after off-pump coronary artery bypass surgery.

Keywords: Coronary artery bypass grafts • Functional capacity • Rehabilitation • Pleurotomy

INTRODUCTION

Coronary artery bypass graft (CABG) surgery remains the treatment of choice to relieve symptoms and improve mortality in selected subgroups of patients with obstructive atherosclerotic coronary artery disease. The left internal thoracic artery (LITA) is deemed the gold standard graft because of its superior long-term patency and outstanding outcomes compared with vein grafts [1]. Despite the evidence supporting LITA graft use, its harvesting has been associated with greater impairment of pulmonary function and changes in pulmonary mechanics leading to increased risk of respiratory complications [2]. This damage is mainly attributed to opening of the pleural cavity during harvesting and the subsequent need for a chest tube through the intercostal space [3–5].

Previous reports demonstrated that shifting the pleural drain insertion site to the sub-xyphoid region promoted better preservation of respiratory muscle strength [5, 6], oxygenation [7] and lung volumes and capacities after CABG with the LITA graft [7, 8].

We hypothesized that changing the position of the pleural drain could also result in better preservation of functional capacity and clinical outcomes. Therefore, the aim of this study was to compare pulmonary shunt fraction, functional capacity and clinical outcomes between patients undergoing pleurotomy with a pleural drain placed in the sub-xyphoid position and patients with a pleural drain inserted in the left intercostal space after off-pump CABG (OPCAB) using the LITA graft.

MATERIALS AND METHODS

This prospective randomized study was performed in the Sao Paulo and Pirajussara Hospitals of the Federal University of Sao
Paulo, Sao Paulo, Brazil. The Institutional Human Ethics Committee approved the protocol and written informed consent was obtained from all the patients.

Patients

Patients undergoing elective first-time OPCAB with the LITA graft harvested according to the skeletonized technique were included. The exclusion criteria were: left ventricle ejection fraction <0.50, patients undergoing emergency surgery, chronic or acute pulmonary disease, acute renal failure, conversion to cardiopulmonary bypass during the operation, incapability to perform spirometry and death.

Initially, 119 patients were screened for inclusion in this study. Sixty-eight fulfilled the inclusion criteria and were analysed. These patients were then randomized into two groups by a computer system. Numbered, sealed and opaque envelopes were used to maintain confidentiality. The groups were as follows: Group II: intercostal pleural drain (n = 33); and Group SI: pleural drain in the sub-xyphoid position (n = 35).

Pulmonary function

Forced vital capacity (FVC) and forced expired volume in 1 s (FEV1) were evaluated bedside using a portable spirometer (Spirobank G, MIR, Rome, Italy) according to the standards of the American Thoracic Society [9]. Tests were performed preoperatively and on postoperative days (POD) 1 and 5 by the same respiratory therapist.

Arterial blood gas measurements [partial pressure of arterial oxygen (PaO2) and partial pressure of carbon dioxide (PaCO2)] and pulmonary shunt fraction were determined preoperatively and on POD 1 with the patient breathing room air. Pulmonary shunt fraction was calculated using the Oxygen Status Algorithm software, (version 2.0; Mads & Ole Sigggaard, Radiometer). This software uses the arterial blood gas and the fraction of inspired oxygen (FiO2) to calculate the percentage of blood that is not supplied by oxygen.

Functional capacity assessment

The sub-maximal functional capacity was assessed by the maximum distance covered in the 6-min walk test (6MWT) preoperatively and on POD 5 as recommended by the American Thoracic Society [10]. All the patients graded their perceived efforts during the test using the 1 to 10 modified Borg rating. The test was always supervised by the same professional who was blind to the patients’ group allocation. The prediction equation proposed by Iwama et al. [11] was used to predict walking distances for all the patients in the preoperative stage.

Anaesthesia and surgical procedure

All the patients received the same anaesthetic technique, induction with etomidate and midazolam, and maintenance with sufentanil and isoflurane (0.5–1%), and were mechanically ventilated with a tidal volume of 8 ml/kg and a respiratory rate adapted to maintain normocapnia, with a 0.5 FiO2 without positive end-expiratory pressure. Intraoperative fluids were given according to the discretion of the anaesthetist.

OPCAB surgery was performed through a median sternotomy, using LITA complemented with additional saphenous grafts. The LITA was taken down in the skeletonized fashion. Meticulous care was routinely taken to preserve the integrity of the pleura during LITA harvesting. Before chest closure, and in the presence of incidental left pleura opening, the site of pleural drain insertion was randomized. A soft tubular straight polyvinyl chloride drain was inserted and exteriorized at the intersection of the sixth left intercostal space (Group II) or a curved one at the sub-xyphoid region and positioned in the left costophrenic sinus (Group SI). In all the patients, a straight mediastinal drain was also placed using a sub-xyphoid approach.

Postoperative management

After the surgical procedure, all the patients were transferred to the cardiac surgery intensive care unit (ICU). While under mechanical ventilation, patients were ventilated on synchronized intermittent mandatory ventilation at 12–14 breaths/min with inspired oxygen fraction to keep arterial oxygen saturation above 90%, an inspiratory/expiratory ratio of 1.2, a positive end-expiratory pressure (PEEP) of 5 cm H2O and pressure support to maintain a tidal volume of 8 ml/kg of predicted body weight. Patients were extubated according to ICU protocol.

All the patients received the same analgesic protocol, 100 mg of tramadol chlorhydrate 4 times daily administered until POD 5, and underwent daily sessions of physical therapy until discharge. Chest tubes were routinely removed on POD 2 and patients were submitted to chest X-ray daily.

Clinical outcomes

Total orotracheal intubation time and length of hospital stay and respiratory events (atelectasis and pleural effusions) were recorded. Pain sensation was assessed on POD 1 and POD 5 before spirometry and quantified by a modified standard score (0 = no pain to 10 = unbearable pain) [12]. Chest X-rays taken preoperatively and on PODs 1, 3 and 5 were evaluated by a radiologist who was blind to the patient group allocation. Pleural effusion was considered relevant when exceeding the phrenocostal angle, and fluid drainage was monitored hourly. Atelectasis was acknowledged when a clear atelectasis radiological shadow exceeded 15 mm in width, linear atelectasis being disregarded in this study.

Statistical analysis

Sample size calculation was based on the distance covered in the 6MWT on POD 5, with a significance level of 5 and 90% power to detect a minimum difference of 54 m. This assumption suggested a sample of 56 patients, resulting in a total of 80 patients to cover losses. Initially, the Kolgomorov-Smirnov test was applied to determine the behaviour of the variables. Data were expressed as means ± standard deviation. When variables were compared between groups, we used the unpaired Student’s t-test and the Mann–Whitney test when necessary. For intragroup analysis, we used the paired Student’s t-test and ANOVA for repeated measures when necessary. For categorical data, Pearson’s χ2 test was performed. The Pearson’s correlation coefficient was used to evaluate associations. The software used for statistical analysis was GraphPad Prism 3.0 (GraphPad, Inc., San Diego, CA, USA). For all statistical tests, the level of significance was set at P <0.05 or 5%.
RESULTS

A flow chart indicating progression of patients throughout the study period is shown in Fig. 1. Groups were homogeneous preoperatively, and no statistical difference was found, as shown in Table 1.

Postoperatively, a significant reduction in pulmonary function occurred in both groups. However, compared with absolute preoperative values, patients with sub-xyphoid pleural drain had better preservation of lung volumes and capacities (Table 2). Pulmonary shunt fraction significantly increased postoperatively for both groups. However, patients in Group SI showed a smaller shunt fraction postoperatively compared with patients in Group II (0.26 ± 0.04 vs 0.21 ± 0.04%; P = 0.0014).

In both groups, there was a significant decrease in the distance covered in the 6MWT compared with preoperative absolute values (P < 0.0001). When groups were compared, patients in group SI walked significantly more than patients in Group II (P = 0.0001) (Table 3). There were significant positive correlations between distance covered in the 6MWT on POD 5 and pulmonary shunt fraction on POD 1 (r = 0.69; P < 0.01) as well as between FVC and distance covered in the 6MWT on POD 5 (r = 0.78; P < 0.01).

Total orotracheal intubation time and hospital stay after surgery were significantly shorter in Group SI compared with Group II (P < 0.05) (Table 4). In addition, significant negative correlation was seen between distance covered in the 6MWT on POD 5 and length of hospital stay after surgery (r = -0.63; P < 0.01).

Patients with sub-xyphoid pleural drain exhibited lower pain scores compared with patients in Group II (P < 0.0001). The incidence of respiratory events on POD 5 was greater in Group II compared with Group SI (Table 4).

DISCUSSION

This randomized, controlled trial demonstrates that, in the postoperative period of patients undergoing OPCAB, the insertion of a pleural drain in the sub-xyphoid position resulted in better preservation of functional capacity, smaller pulmonary shunt fraction and better clinical outcomes compared with the intercostal site.

To the best of our knowledge, this is the first randomized controlled trial to investigate whether changing the site of insertion of a pleural drain to the sub-xyphoid position could positively impact on functional capacity, pulmonary shunt fraction and clinical outcomes after CABG, without the negative effects of cardiopulmonary bypass.

Pulmonary function is strongly affected after heart surgery. The use of general anaesthesia during the procedure results in loss of respiratory muscle tone, decreased lung compliance and increase in total respiratory system resistance [13]. Median sternotomy impairs lung function, causes pain and alters the chest wall compliance. It also slows lung function recovery with increased morbidity during the early postoperative period [14]. Studies show that on-pump CABG surgery results in a greater degree of lung dysfunction during the early postoperative period compared with OPCAB [15, 16]. Nevertheless, pulmonary dysfunction is more pronounced when LITA is used, and its use is often associated with pleura opening with consequent need for intercostal pleural
drainage, further damaging lung function postoperatively compared with intact pleura [2–4].

The site of insertion of a pleural drain after opening the pleural cavity (pleuroscopy) has been reported as a determinant of lung function and clinical outcomes post-CABG. Regardless of cardiopulmonary bypass use, previous studies demonstrated lower pulmonary dysfunction and lower pain scores after CABG with a pleural drain in the sub-xyphoid site [7, 8]. In a recent study [6], it was demonstrated that sub-xyphoid pleural drainage provided better preservation of respiratory muscle strength compared with intercostal pleural drainage, with lower pain levels and shorter hospitalization and intubation times. In our study, similar results were also found, and the change of pleural drain insertion site to the sub-xyphoid position attained better preservation of lung volumes and capacities with lower pain levels during the early postoperative period following OPCAB.

Concerning the pulmonary shunt fraction, previous studies demonstrated increased pulmonary shunt during early postoperative period following CABG independent of the surgical technique used [5, 13, 14]. The present study found similar results: both groups showed a significant increase in pulmonary shunt fraction on POD1. However, patients who received a sub-xyphoid chest tube exhibited a significantly lower pulmonary shunt fraction compared with patients with intercostal drain. This result may demonstrate that shifting the pleural drain site has a positive effect on pulmonary oxygenation recovery.

The 6MWT is a reliable clinical exercise test for evaluating functional capacity, and is both an indicator of prognosis and an outcome measure [10]. The walking capacity allows identification of more severely compromised patients with lower susceptibility to recovery [17].

The distance covered in the 6MWT is significantly lower after CABG surgery compared with preoperative values [18, 19], and these results were confirmed by this trial. Many factors may contribute to this result, including trauma to the chest wall (sternotomy and insertion of pleural drains), impaired respiratory function, bed rest and pain. Functional capacity has been associated with pulmonary function after CABG. Previous studies reported that respiratory muscle strength is strongly related to functional status after cardiac surgery. Patients with increased respiratory muscle strength have been demonstrated to walk significantly further than individuals with impaired respiratory strength after CABG [20].

In this study, Group SI had a smaller decrease (21%) in the distance covered in relation to preoperative levels compared with Group II (31% drop). In this context, shifting the pleural drain site from an intercostal site to the sub-xyphoid region had a positive impact on the functional capacity expressed by improved recovery in the distance covered during the 6MWT, bettering exercise tolerance on early postoperative measurements.

These findings can be explained by the positive correlation between distance covered and FVC on POD5 and between pulmonary shunt fraction on POD1 and distance covered on POD5. Thus, in the sub-xyphoid group, probably as a result of less trauma to the chest, the attained lower pulmonary shunt fraction on POD1 and better preservation of lung volumes resulted in a greater distance being covered during the 6MWT.

Evidence shows that a greater degree of pulmonary dysfunction increases the risk of respiratory events during the postoperative period [3–5, 21]. A recent investigation by Sensoz et al. [22] demonstrated that intercostal pleural drains presented the same drainage capacity for pleural effusion as sub-xyphoid drains, but the use of sub-xyphoid pleural drains can reduce the incidence of atelectasis during the CABG postoperative period. In the present study, similar results were found, with greater incidence of atelectasis and pleural effusion in Group II than in Group SI. Our findings

### Table 1: Pre- and intraoperative clinical and demographic characteristics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group II (n = 33)</th>
<th>Group SI (n = 35)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>57.0 ± 7.7</td>
<td>59.6 ± 8.4</td>
<td>0.09</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male/female</td>
<td>25/8</td>
<td>22/13</td>
<td>0.12</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.6 ± 3.6</td>
<td>25.2 ± 3.7</td>
<td>0.30</td>
</tr>
<tr>
<td>Pulmonary function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FVC (l)</td>
<td>3.3 ± 0.4</td>
<td>3.5 ± 0.2</td>
<td>0.38</td>
</tr>
<tr>
<td>% Predicted</td>
<td>95.5 ± 12.7</td>
<td>91.5 ± 9.4</td>
<td>0.11</td>
</tr>
<tr>
<td>% Predicted</td>
<td>101.1 ± 11.8</td>
<td>97.9 ± 7.8</td>
<td>0.02</td>
</tr>
<tr>
<td>PaO₂ (mmHg)</td>
<td>79.3 ± 9.4</td>
<td>78.6 ± 7.1</td>
<td>0.38</td>
</tr>
<tr>
<td>PaCO₂ (mmHg)</td>
<td>36.4 ± 3.3</td>
<td>38.7 ± 2.9</td>
<td>0.52</td>
</tr>
<tr>
<td>Pulmonary shunt fraction (%)</td>
<td>0.02 ± 0.02</td>
<td>0.03 ± 0.02</td>
<td>0.10</td>
</tr>
<tr>
<td>6MWT (m)</td>
<td>505.6 ± 47.2</td>
<td>495.3 ± 36.5</td>
<td>0.15</td>
</tr>
<tr>
<td>% Predicted</td>
<td>90.0 ± 18.8</td>
<td>90.0 ± 6.8</td>
<td>0.42</td>
</tr>
<tr>
<td>Surgery time (min)</td>
<td>309.9 ± 30.7</td>
<td>314.4 ± 28.9</td>
<td>0.11</td>
</tr>
<tr>
<td>Grafts per patient (n)</td>
<td>2.7 ± 0.3</td>
<td>2.6 ± 0.5</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Data expressed as mean ± standard deviation.
II: intercostal insertion; SI: sub-xyphoid insertion; BMI: body mass index; FVC: forced vital capacity; FEV₁: forced expiratory volume in 1 s; PaO₂: partial arterial pressure of oxygen; PaCO₂: partial arterial pressure of carbon dioxide; 6MWT: 6-min walking test absolute value in metres.

### Table 2: Pulmonary function values on the postoperative days 1 and 5, as a percentage of the preoperative values

<table>
<thead>
<tr>
<th>Variables (%)</th>
<th>POD 1 Group II</th>
<th>POD 1 Group SI</th>
<th>P</th>
<th>POD 5 Group II</th>
<th>POD 5 Group SI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>38.7 ± 9.8</td>
<td>50.3 ± 10.3</td>
<td>0.0001</td>
<td>61.9 ± 7.2</td>
<td>75.8 ± 8.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>FEV₁</td>
<td>40.7 ± 8.4</td>
<td>48.5 ± 7.1</td>
<td>0.003</td>
<td>62.3 ± 5.8</td>
<td>77.3 ± 8.4</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Data expressed as mean ± standard deviation; P-values refer to the difference between groups. FVC and FEV₁ expressed in percentage given a 100% preoperative baseline value.
II: intercostal insertion; SI: sub-xyphoid insertion; FVC: forced vital capacity; FEV₁: forced expiratory volume in 1 s; POD: postoperative day.
suggest that better preservation and recovery of lung volumes and functional capacity, smaller pulmonary shunt fraction and shorter intubation time appear to have been partially responsible for the lower incidence of respiratory events and consequent reduction in hospitalization length observed in patients with sub-xyphoid drains compared with intercostal drains. Although this study has not been designed to evaluate hospital costs, the significant reduction in the time of intubation and hospital stay for patients during the postoperative period may infer lower hospital costs with the sub-xyphoid drain strategy.

The results of this study can be explained by several factors. The placement of intercostal pleural drains increases trauma to the rib cage, which leads to ventilatory-dependent pain and shallow breathing with major decreases in lung volume [21]. This results in alveolar collapse identified in this study by increased pulmonary shunt fraction, increasing the risk of respiratory events and, thus, influencing functionality and exercise tolerance during the postoperative period.

Impaired functionality can cause significant limitations in activities of daily living (ADLs) [17–20]. In accordance with these studies, and given the results of the present study, we believe that the loss of functionality during the early postoperative period could increase the length of hospital stay and affect the quality of life and, therefore, must be considered a relevant factor in the prognosis at the hospital discharge. In the present study, the correlation between 6MWT on POD5 and hospital stay after surgery showed that the shorter the distance covered, the longer the length of hospital stay.

The determinant of physiological and clinical outcomes after CABG surgery encompasses the pleural drain site, not the pleurotomy itself. In previous studies, pleurotomy with intercostal pleural drainage was responsible for greater impairment of lung function and longer hospital stays compared with intact pleura [2]. Conversely, pleurotomy with insertion of a pleural drain in the sub-xyphoid position, thus avoiding the intercostal spaces, better preserves lung function and yields clinical results similar to those of maintaining the pleura integrity [5].

In this study, it can be observed that reduced chest wall trauma determined better functional performance with improved exercise tolerance at the time of hospital discharge. We speculate that the better functional status allows the patient go for stages II and III of cardiac rehabilitation in optimum working conditions. In addition, this could have clinical significance, because those patients with a more preserved functional status may return faster to their ADLs. Therefore, based on these findings, we strongly recommend that, when the pleural cavity is opened, especially in high-risk patients, the site of the drain be changed to the sub-xyphoid position.

**STUDY LIMITATIONS**

Even though the sample size was calculated and resulted in several patients sufficiently addressed by the quantity of individuals included in this trial, the size of the population included in this study may not be sufficient to reflect general practice. Nevertheless, it may be unethical to include more patients in the intercostal group if statistics demonstrate the advantage and benefits of sub-xyphoid approach.

The decrease in the distance covered after CABG is inevitable. Unfortunately, the amount of change distance (Δ6MWT) that should be considered clinically relevant between pre- and postoperative has not been well studied. Previous studies [23–25] used the absolute value of the distance covered postoperatively as a percentage of the predicted value. A cut-off that determines the prognostic value and clinical impact of a fall in the distance covered in the postoperative stage using a preoperative baseline of 100% has not yet been reported. In this study, we found that a decrease of 30% in relation to absolute preoperative value resulted in longer hospital stays and worse clinical outcomes in patients with intercostal drains. Thus, additional studies that explore the clinical significance of the decrease in functional capacity using the distance covered in the 6MWT early after CABG are mandatory.

**CONCLUSION**

Regardless of the drain insertion site, both groups showed an increase in pulmonary shunt fraction and reduced functional capacity during the early postoperative period following OPCAB. However, the sub-xyphoid pleural drain position determined better functional capacity and exercise tolerance with smaller pulmonary shunt fraction and improved clinical outcomes compared with intercostal pleural drainage.

Conflict of interest: none declared.
REFERENCES