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Subxyphoid pleural drain confers lesser impairment in respiratory muscle strength, oxygenation and lower chest pain after off-pump coronary artery bypass grafting: a randomized controlled trial

Dreno pleural subxifoide confere menor comprometimento da força muscular respiratória, oxigenação e menor dor torácica após cirurgia de revascularização do miocárdio sem circulação extracorpórea: estudo controlado randomizado

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Abstract

Objective: **To evaluate respiratory muscle strength, oxygenation and chest pain in patients undergoing off-pump coronary artery bypass (OPCAB) using internal thoracic artery grafts comparing pleural drain insertion site at the subxyphoid region versus the lateral region.**

Methods: **Forty patients were randomized into two groups in accordance with the pleural drain site. Group II (n = 19) - pleural drain exteriorized in the intercostal space; group (SI) (n = 21) chest tube exteriorized at the subxyphoid region. All patients underwent assessment of respiratory muscle strength (inspiratory and expiratory) on the pre, 1, 3 and 5 postoperative days (POD). Arterial blood gas analysis was collected on the pre and POD1. The chest pain sensation was measured 1, 3 and 5 POD.**

Results: **A significant decrease in respiratory muscle strength (inspiratory and expiratory) was seen in both groups until POD5 (*P* <0.05). When compared, the difference between groups remained significant with greater decrease in the II (*P* <0.05). The blood arterial oxygenation fell in both groups (*P* <0.05), but the oxygenation was lower in the II (*P* <0.05). Referred chest pain was higher 1, 3 and 5 POD in the II group (*P* <0.05). The orotracheal intubation time and postoperative length of hospital stay were higher in the II group (*P* <0.05).**

Conclusion: **Patients submitted to subxyphoid pleural drainage showed less decrease in respiratory muscle strength, better preservation of blood oxygenation and reduced thoracic pain compared to patients with intercostal drain on early OPCAB postoperative.**

Descriptors: **Myocardial revascularization. Coronary artery bypass, off-pump. Pulmonary gas exchange. Respiratory function tests. Respiratory mechanics.**

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Abbreviations, acronyms & symbols	
BMI	body mass index
CABG	coronary artery bypass surgery
CPB	cardiopulmonary bypass
FEV1	forced expiratory volume in one second
FVC	forced vital capacity
Group II	intercostal insertion group
Group SI	subxyphoid insertion group
ICU	intensive care unit
ITA	internal thoracic artery
LITA	left internal thoracic artery
MEP	maximal expiratory pressure
MIP	maximal inspiratory pressure
OPCAB	off-pump CABG
OTI	orotracheal intubation time
$PaCO_2$	partial pressure of carbon dioxide
PaO_2	partial pressure of arterial oxygen
PEEP	positive end expiratory pressure
POD	postoperative day
PVC	polyvinyl chloride

Resumo

Objetivo: **Avaliar a força muscular respiratória, oxigenação e dor torácica em pacientes submetidos à cirurgia de revascularização miocárdica (RM) sem circulação extracorpórea (CEC) comparando o local de inserção do dreno pleural na região subxifoidea versus lateral.**

Métodos: **Quarenta pacientes foram randomizados em dois grupos Grupo (II - n = 19) - dreno pleural exteriorizado na região intercostal; Grupo (SI - n = 21) dreno pleural exteriorizado na região subxifoidea. Os pacientes foram submetidos à avaliação da força muscular respiratória no pré, 1°, 3°e 5° dias de pós-operatório (PO). Gasometria arterial foi coletada no pré e 1° dia do PO. A dor torácica foi avaliada no 1°, 3° e 5° dias de PO.**

Resultados: **Ambos os grupos apresentaram diminuição significante da força muscular respiratória até o quinto dia do PO (*P* <0,05). A diferença entre os grupos manteve-se significante com maior decréscimo no grupo II (*P* <0,05). Houve queda na pressão arterial de oxigênio em ambos os grupos (*P* <0,05), mas quando comparado à queda foi maior no grupo II (*P* <0,05). A dor torácica no 1°, 2° e 5° dia do PO foi maior grupo II (*P* <0,05). O tempo de intubação orotraqueal e permanência hospitalar no PO foram maiores no grupo II (*P*<0,05).**

Conclusão: **Pacientes submetidos a drenagem pleural subxifoidea apresentaram menor queda na força muscular respiratória, melhor preservação da oxigenação arterial e menos dor comparado aos pacientes com inserção do dreno na região intercostal no PO precoce de cirurgia de RM sem CEC.**

Descritores: **Revascularização miocárdica. Ponte de artéria coronária sem circulação extracorpórea. Troca gasosa pulmonar. Testes de função respiratória. Mecânica respiratória.**

INTRODUCTION

Despite advances in surgical techniques and improvements in perioperative care, cardiac surgery is still associated with increased morbidity and mortality. Patients undergoing coronary artery bypass surgery (CABG) present postoperative reduced lung function, disregarding the operative technique employed. The factors responsible for these disorders are routinely the general anesthesia, need of median sternotomy, phrenic nerve dysfunction and use of cardiopulmonary bypass (CPB). Currently, internal thoracic artery (ITA) has been used as graft of choice due to the excellent patency and greater long-term survival when compared to saphenous vein grafts [1,2].

However, pulmonary dysfunction is more pronounced when left ITA (LITA) is mobilized owing to the frequent opening of the pleural cavity, with consequent need of pleural drainage. Conventionally, the chest tube is exteriorized through intercostal space, with increased chest wall trauma and pain, contributing to lower respiratory capacity. This fact leads to decrease of cough effectiveness, favors secretion accumulation and increase the risk of pulmonary complications. The shift of pleural drain site from intercostal to the subxyphoid position might interfere in the degree of lung volumes commitment and capacities in the early CABG postoperative. Previous studies demonstrated that, independently of CPB use, drain insertion in the subxyphoid region is able to afford better preservation of spirometric parameters in the CABG postoperative period when compared to the intercostal region [3,4].

Our hypothesis is that the chest tube exteriorized at the subxyphoid region could also promote lower chest pain and better preservation of the respiratory muscle strength in the early postoperative period of off-pump CABG (OPCAB). Therefore the aim of this study was to evaluate respiratory muscle strength, oxygenation and chest pain in patients undergoing OPCAB using LITA comparing the pleural drain insertion site in the subxyphoid versus intercostal region.

METHODS

Patient selection

This prospective randomized controlled study was conducted at Bandeirantes and Pirajussara Hospitals. The Human Ethics Committee of the Federal University of São Paulo approved the protocol and written informed consent was obtained from all patients. Inclusion criteria were: patients with obstructive atherosclerotic coronary artery disease and referred to elective OPCAB, left ventricular ejection fraction greater than 50%, age between 35 and 75, hemodynamic stability during measurement of respiratory muscle strength and spirometry. The exclusion criteria were patients with previous pulmonary disease assessed by spirometry in preoperative; conversion to CPB, bilateral opening of pleural cavities, patients who failed or refused to perform the respiratory muscle strength test.

Forty patients who underwent elective OPCAB using LITA with pleurotomy and left pleural drainage were included, and randomized into two groups by computer system (numbered, opaque and sealed envelopes), in accordance with the drain position: Group (II) or intercostal insertion (n = 19) drain exteriorized at the intersection of sixth intercostal space in the midaxillary line; Group (SI) or subxyphoid insertion (n = 21) with drain inserted in the subxyphoid region.

Respiratory muscle strength evaluation

Evaluation of respiratory muscle strength consisted of measurement of maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) by an analog manovacuometer (GerAr med®). The recordings were performed at preoperative, 1, 3 and 5 postoperative day (POD) and the results were expressed as percentage of the preoperative period. The measurements were performed in the Fowler position (45 degrees), each maneuver was performed five times with 1 minute rest between them, and the value of sustained pressure during 2 seconds by the patient was recorded, according with the guidelines of pulmonary function tests [5].

The MIP was measured from residual volume, the patient was requested to perform a forced expiration and then take a maximal inspiratory effort against an occluded airway (Mueller maneuver). The MEP was measured from total pulmonary capacity; the patient was instructed to perform a forced inspiration followed by a maximal expiratory effort against an occluded airway (Valsalva maneuver). The MIP and MEP were obtained using a pressure transducer connected to a system with two unidirectional valves. This measurement was always performed by the same professional.

The spirometry was performed preoperatively to evaluate and discard patients with chronic obstructive or restrictive pulmonary diseases, according to American Thoracic Society [6].

Arterial blood gas measurements

Arterial blood gas measurements (partial pressure of arterial oxygen [PaO_2] and partial pressure of carbon dioxide [$PaCO_2$]) were determined at preoperative and 1 POD with patient breathing room air, always before the measurement of respiratory muscle strength.

Intraoperative

Anesthesia and ventilation management

All patients received a standard anesthetic technique, induction with etomidate and midazolam, maintenance with sufentanil and isofluorane (0.5% to 1%) and were mechanically ventilated to maintain normocapnia, with a 50% inspired oxygen fraction without positive end-expiratory pressure. Intraoperative fluids were given according to the anesthetist discretion.

Operative technique

The OPCAB surgery was performed through a median sternotomy, using LITA complemented with additional saphenous vein grafts. The LITA was harvested in a skeletonized fashion. Before chest closure, and in the presence of left pleura opening, the site of drain insertion was randomized.

A soft tubular straight PVC drain was inserted and exteriorized at the intersection of the sixth left intercostal space or a curved one at the subxyphoid region and positioned in the left costophrenic sinus.

Postoperative management

All patients were transferred to the intensive care unit (ICU) with orotracheal intubation, inspired oxygen fraction to keep arterial oxygen saturation above 90%, predicted tidal volume of 8 ml/kg, positive end expiratory pressure (PEEP) of 5 cmH_2O and extubated according to ICU protocol. All patients received the same analgesic protocol administered during the postoperative period. The drains (mediastinal and/or pleural) were routinely removed on POD2 and all patients were submitted to a physical therapy program until hospital discharge (breathing exercises and early deambulation). Chest pain sensation was assessed on 1, 3 and 5 PODs, and quantified by a modified standard score (0 = no pain to 10 = unbearable pain) [7]. This evaluation was performed at rest before the measurement of respiratory muscle strength. The time of intubation and hospital stay after surgery were also recorded.

Statistical analysis

Variables were described as mean ± standard deviation. The PaO_2, MIP and MEP were converted and analyzed with the values expressed in percentage of preoperative value, considered as 100% the preoperative baseline value. The paired t Student test was used to compare two intragroup timetables. For over time comparison, the analysis of variance (ANOVA) for repeated measures was applied. When the groups were compared (group II versus group SI) the Mann-Whitney test or Student's t unpaired test were used. The analysis of categorical data was performed by Pearson chi-square test. Statistical analysis was performed by GraphPad Prism 3.0 Software (GraphPad Software Inc, San Diego, CA). For all statistical tests, the significance level adopted was alpha <0.05 or 5%.

RESULTS

During the study period, 143 patients fulfilled eligibility criteria. From that sample, 40 were actually analyzed (Figure 1). The formed groups were homogeneous in relation to age, sex, body mass index, preoperative lung function, surgery time, number of grafts per patient, with no significant statistically differences, as shown in Table 1.

Table 1. Pre and intraoperative clinical and demographic parameters.

Variables	Group II (N=19)	Group SI (N=21)	*P*
Age(years)	57.37 ± 10.83	53.86 ± 10.30	0.30
Gender(n)			
Male	11	4	0.11
Female	8	17	
BMI(kg/m²)	26.51 ± 3.66	28.11± 4.71	0.23
Pulmonary function			
FVC(l)	3.46 ± 0.64	3.60 ± 0.44	0.44
FEV_1(l)	3.02 ± 0.60	3.21 ± 0.52	0.38
PaO_2(mmHg)	81.33 ± 9.80	77.67 ± 8.19	0.20
$PaCO_2$(mmHg)	37.40 ± 3.35	38.00 ± 2.94	0.55
MIP(cmH_2O)	76.89 ±21.15	81.25 ± 26.49	0.29
% predicted	84.76 ± 18.32	75.72 ± 19.09	
MEP(cmH_2O)	93.89 ± 24.70	93.00 ± 30.00	0.46
% predicted	84.76 ± 18.32	75.72 ± 19.09	
Surgery time(min)	312.9 ± 29.78	306.4 ± 22.98	0.34
Grafts per patient(n)	2.78 ± 0.41	2.52 ± 0.87	0.44

Data are shown as mean ± standard deviation. BMI = body mass index; FEV_1 = Forced expiratory volume in 1 second; FVC = forced vital capacity; II = intercostal insertion; SI = subxyphoid insertion; $PaCO_2$ = partial arterial carbon dioxide pressure; PaO_2 = partial arterial oxygen pressure; MEP = maximal expiratory pressure; MIP = maximal inspiratory pressure

Table 2. Maximal inspiratory pressure values are presented in 1, 3 and 5 PODs. Absolute values and as the percentage of the preoperative values in groups II and SI.

Group II	POD1	POD3	POD5
MIP(cmH_2O)	39.58±12.92*	44.62±10.89*	53.09±9.84*
% Post/pre	51.48±12.05	58.04±16.07	69.05±15.62
Group SI			
MIP(cmH_2O)	49.96±12.05*†	56.68±16.07*†	67.29±15.62*†
% Post/pre	61.49±10.80	69.77±10.89	82.82±15.62

*Data expressed as mean ± standard deviation. * P <0.05 compared to the value of preoperative and † P <0.05 for comparison between groups II and SI. (MIP = maximal inspiratory pressure; POD = postoperative day; % post/pre = percentage of postoperative in relation to preoperative)*

A significant decrease in inspiratory and expiratory muscle strength in both groups was found until the POD5 (*P* <0.001), when compared with preoperative values. In the comparison between groups, the difference remained significant in 1, 3 and 5 PODs, with even greater reduction in group II (Tables 2 and 3).

There was a significant drop in PaO_2 in the POD1 for both groups in relation to preoperative values (*P* <0.05). Between groups, the percentage of PaO_2 in relation to preoperative was significantly higher in the SI group compared to the II group (72.40 ± 11.01% versus 86.21 ± 7.67%, *P* <0.0001). The $PaCO_2$ values increased in both groups in the POD1 but this increment was not statistically significant in the SI group (*P* = 0.11). When compared, the II group showed significantly higher value (47.73 ± 8.68 versus 39.77 ± 4.02, *P* <0.05). The chest pain sensation was greater in group II (*P*<0.0001) (Table 4). Orotracheal intubation time and the hospital stay were also higher in the II group (Table 5).

Table 3. Maximal expiratory pressure values are presented in 1, 3 and 5 PODs. Absolute values and as the percentage of the preoperative values in groups II and SI.

Group II	POD1	POD3	POD5
MEP(cmH_2O)	49.89±11.02*	59.57±9.08*	66.88±10.90*
% Post/pre	53.14±12.79	63.45±12.91	71.24±12.26
Group SI			
MEP(cmH_2O)	61.49±12.07*†	69.59±12.01*†	78.23±12.98*†
% Post/pre	66.12±15.88	74.83±12.75	84.12±10.69

*Data expressed as mean ± standard deviation. * P <0.05 compared to the value of preoperative and † P <0.05 for comparison between groups. (MEP = Maximal expiratory pressure; POD = postoperative day; % post/pre = percentage of postoperative in relation to preoperative)*

Table 4. Values of subjective chest pain sensation on 1, 3 and 5 PODs.

	Grupo II	Grupo SI
POD1	8.73±1.09	6.14±1.49*
POD3	7.15±1.06	4.81±1.80*
POD5	3.89±1.19	1.95±0.97*

*Data expressed as mean ± standard deviation. * P<0.05 comparison between groups. (POD= postoperative day; II = intercostal insertion; SI = subxyphoid insertion)*

Table 5. Orotracheal intubation time and hospital stay on postoperative period in the II and SI groups

	Group II	Group SI	*P*
OTI (hours)	10.93 ± 1.25	9.39±1.96	*P* <0.006
Hospital stay (days)	7.36 ± 1.38	5.61±0.97	*P* <0.0001

Data expressed as mean ± standard deviation. P values for comparison between groups. (OTI = orotracheal intubation time, II = intercostal insertion, SI = subxyphoid insertion)

DISCUSSION

Regardless of the drain position, a decrease of respiratory muscle strength and oxygenation was noticed in the OPCAB postoperative period. However, the drain insertion in the subxyphoid region was able to afford better preservation of oxygenation and respiratory muscle strength (MIP and MEP).

A deterioration of lung volumes and respiratory muscle strength in the CABG postoperative period is evident. After surgery, there is a 40% to 60% drop in volumes and capacities in relation to preoperative values [8,9]. Several factors are responsible for this postoperative pulmonary dysfunction. General anesthesia alters the ventilation-perfusion and functional residual capacity; and increase pulmonary vascular resistance through the mechanism of hypoxic pulmonary vasoconstriction. The sternotomy changes the chest compliance, induces decline of more than 80% of its mobility, promoting decrease of the pulmonary compliance and alveolar collapse [10].

Guizilini et al. [11] in a study comparing median sternotomy versus ministernotomy in OPCAB observed that the ministernotomy resulted in better preservation and recovery of lung function, probably due to less trauma caused to the ribcage. As a result, patients had less time of orotracheal intubation and hospital stay. Therefore, CPB avoidance and limited incisions may provide a faster recovery and earlier hospital discharge.

Evidence shows that changes in pulmonary function in patients undergoing on-pump cardiac surgery are largely responsible for morbidity. The emergence of OPCAB techniques have minimized intraoperative and postoperative complications, resulting in shorter hospitalization. Guizilini et al. [8] demonstrated that patients underwent off-pump surgery had better preservation of pulmonary function when compared to those on-pump. Recently, Silva et al. [12] demonstrated that significant deterioration in lung function occurs following either on- and off-pump CABG. However, a greater decrease was found in patients undergoing on-pump CABG.

Pulmonary dysfunction is more pronounced when LITA is used due to the frequent opening of the pleural cavity, with the consequent need for intercostal pleural drainage. New techniques with pleural drain inserted at the subxhyphoid site clearly afforded better preservation of lung volumes and capacities; and reduction of pain compared to the intercostal region [4,8].

To the best of our knowledge this is the first randomized controlled trial addressing the questioning whether changing the site of pleural drain to subxyphoid region may interfere on respiratory muscle strength, thoracic pain and oxygenation after OPCAB.

Respiratory muscle strength after CABG is also affected, the reduction of respiratory muscle strength has been reported as a factor that potentiate the reduction of volume and capacity in the postoperative period, possibly raising the risk of pulmonary complications [13,14].

During anesthesia, displacement of blood from the chest to the abdomen results in increased abdominal pressure. These volume changes affect the diaphragm curvature, which according to Laplace's law is important for the muscle to keep its capacity to generate pressure. As a result, the radius of the diaphragm increases, which harms the diaphragmatic dynamics interfering at the muscle strength in the early postoperative.

The CPB may increase the degree of diaphragmatic dysfunction potentiating the decrease of inspiratory muscle strength. Therefore, in this study CPB was eliminated in order to avert its additional effects in the respiratory muscles.

The ITA use may represent an additional surgical trauma and decrease the blood supply to the intercostal muscles and diaphragm, due to phrenic nerve ischemia and lesion of pericardico-phrenic artery during harvesting, further reducing inspiratory muscle strength [15].

In this study, even eliminating CPB, manipulation of the whole surgical procedure determined decrease in respiratory muscle strength (MIP and MEP) until POD5, in accordance to the study of Borghi-Silva et al. [16]. Even though, the preoperative values were not restored until discharge, similar finding to the study of Morsch et al. [14]. However the intercostal group showed a greater decrease of MIP and MEP compared to subxyphoid insertion. These results reinforce that the chest tube in the intercostal region may be a contributing factor for the decline in respiratory muscle strength in the early postoperative period of CABG.

The weakness of respiratory muscles is one of the mechanisms that contribute to the restrictive ventilatory disorder with consequent hypoxemia [17]. After CABG, regardless of the technique employed, a drop in PaO_2 in the first days is seen with gradual recovering [18,19].

In this study, even avoiding CPB, a significant decrease of PaO_2 on POD1 was observed in both groups. The group II presented a 27.6% reduction, while the smallest decrease of 13.79% was found on SI group. Similar results were found by Guizilini et al [3]. In the Hagl et al. [4] study, the need for supplemental oxygen was lower in patients with subxyphoid insertion. Therefore, the drain positioned at the intercostal region seems to impact PaO_2 deterioration after surgery.

Several mechanisms might explain the hypoxemia: alveolar hypoventilation, altered ventilation- perfusion ratio, reduction of diffusion and shunt. The alveolar hypoventilation could in part contribute to the postoperative hypoxemia observed in both groups, because $PaCO_2$ on POD1 values were significantly higher than preoperative ones, similar to previous studies [3]. Certainly this factor contributed to the worsening of the hypoxemia in patients with intercostal tube drainage, the values of $PaCO_2$ in group II were significantly higher compared to SI group.

Earlier reports show that patients with greater pain after CABG present increased risk for pulmonary complications due to the immobility and deep breathing absence. Patients with pleural opening had more pain associated with a greater reduction in lung volumes and capacities during the first week after surgery [20,21]. Hagl et al. [4] also showed that pain in patients with subxyphoid drain position was lower compared to intercostal tube drainage. Pick et al. [22] showed that this pain caused by intercostal drainage is able to add respiratory dysfunction postoperatively. In this present study similar results were found. The referred pain was significantly higher in patients with intercostal pleural drain until POD5 and was associated to a greater decrease in respiratory muscle strength. This greater reduction in respiratory muscle strength with intercostal chest tube may be due to further trauma consequent to the worse chest pain [23].

Several factors can be blamed by these findings. The additional need for a chest lateral incision for tube placement, the intercostal opening leads to periosteum and intercostal nerve irritation, impairing the intercostal muscles performance. The friction between the tube and the parietal pleura during breathing triggers ventilatory-dependent pain and superficial breathing resulting in major decreases in lung volume, alveolar hypoventilation and subsequent hypoxia, predisposing lung function worsening with increased risk for respiratory complications [24,25].

Our findings suggest that better preservation of respiratory muscle strength and oxygenation appear to have been partly responsible for the shorter intubation time and consequent reduced hospital stay observed in patients with subxyphoid drain once compared to patients with intercostal drain.

It may be inferred that the significant reduction of intubation time and hospital stay after surgery are indicators of lower hospital costs for patients with subxyphoid drain. Therefore, these results suggest that once the pleural cavity is opened, change the drain position to subxyphoid region is recommended.

CONCLUSION

Patients submitted to subxyphoid pleural drainage showed less decrease in respiratory muscle strength, better preservation of blood oxygenation and reduced thoracic pain compared to patients with intercostal drain on early OPCAB postoperative.

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