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ORIGINAL ARTICLE

Open Versus Closed Pleura Internal Mammary Artery Harvesting and Early Pulmonary Functions After Coronary Artery Bypass Grafting

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Background The internal mammary artery is the vessel of choice for myocardial revascularisation during coronary artery bypass grafting (CABG). Although it is possible to harvest the left internal mammary artery (LIMA) without opening the left pleura, pleurotomy is usually performed to provide adequate exposure and allow the placement of the LIMA medial to the upper lobe, preventing any undue tension on the mammary pedicle. However, the intact pleura technique may have a lower risk of postoperative pulmonary complications. We aimed to study the effects of both procedures on pulmonary function and the incidence of complications.

Method One hundred patients with ischaemic heart disease indicated for CABG were included and divided into two groups. The closed pleural technique group included 50 patients with preservation of the pleural integrity during mammary harvesting. The open pleural procedure group included 50 patients without preservation of pleural integrity. Spirometry was done pre- and postoperatively in both groups and postoperative pulmonary complications in both groups were recorded and analysed.

Results Internal mammary harvesting with preservation of pleural integrity during CABG in patients in the closed pleural procedure group showed significant improvement in forced expiratory volume in the first second (FEV1%), forced vital capacity (FVC%), and FEV1/FVC compared with the corresponding values in patients in the open pleural procedure group, on day 5 postoperatively, at discharge, and at day 30. There were fewer complications in preservation of pleural integrity with regard to lung atelectasis and pleural effusion, which were significantly lower in patients in the open pleural procedure group.

Conclusions Preservation of pleural integrity has beneficial effects on pulmonary functions and has fewer associated pulmonary complications.

Keywords CABG • Pulmonary function • Internal mammary artery • Pleural integrity

Introduction

The internal mammary artery (IMA) is one of many alternatives and is widely used as the conduit of choice for myocardial revascularisation during coronary artery bypass grafting (CABG) [1]. The most commonly used techniques for IMA harvesting include open pleurotomy and extrapleural IMA [2]. Respiratory complications in patients

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undergoing CABG may affect postoperative mortality rates [3].

It is well known that most patients with ischaemic heart disease are current or ex-smokers and are thus liable to more pronounced postoperative pulmonary complications [4]. Additional adverse effects of extracorporeal circulation on respiratory system protection may also lead to excessive postoperative mucus secretion and atelectasis [5].

There are evidence-based data that impairment of pulmonary functions in patients undergoing CABG is more pronounced when IMA grafts are used [6]. Furthermore, pleurotomy during IMA harvesting may also impair respiratory function in the postoperative period [7], and may produce some overt postoperative complications [8].

Pulmonary complications after CABG may be secondary to cardiac dysfunction, for example pulmonary oedema and congestive heart failure, or due to intrinsic pulmonary problems, such as atelectasis and pneumonia, or result from cardiopulmonary bypass, specifically postperfusion lung syndrome (acute respiratory distress syndrome secondary to cardiopulmonary bypass) [9], or related to surgical techniques, such as pleural effusion, pneumothorax, and haemothorax [10]. For IMA harvesting, some surgeons advocate for leaving the pleura intact, while others prefer the open pleural technique [11]. Each of the two surgical methods has its advantages and hazards, which could affect long-term morbidity and mortality. In this study we compared the effect of both techniques on pulmonary function and on postoperative complications, in order to determine the best choice for patients.

Patients and Methods

A prospective randomised controlled study was conducted on 100 patients with ischaemic heart disease, who had undergone elective first-time CABG. Patients were divided into two similar groups to detect the significant difference between them: 50 patients were included in the closed pleura left IMA (LIMA) harvesting group (CP group); and 50 patients were included in the open pleura LIMA harvesting group (OP group; control group). Patients were recruited from the Mahalla Cardiac Center and Benha University Hospitals. Institutional ethics committee approval was obtained, and written informed consent was obtained from all patients or their relatives before enrolment in the study, after providing them with a full explanation of the methodology to be used.

There were two teams of surgeons. One team used the closed technique, and the other used the open technique. All methods were planned before surgery. None of the cases was cancelled because of the surgical approach. In the CP group, none of the cases was converted to open pleural owing to accidental pleural opening during sternotomy or LIMA harvesting. In the OP group, the pleurae were opened along the whole length of LIMA pedicle.

All patients were thoroughly evaluated pre- and intraoperatively.

Preoperative pulmonary function tests (PFTs) were done on all patients.

We assessed all 100 patients at 5 days postoperatively, on the day of hospital discharge, and on day 30 postoperatively. Collected data included the patients' clinical status, plain chest X-ray, and chest computed tomography (CT; evaluation was undertaken by a chest physician and surgeons and was not dependent on surgical technique), and PFTs (forced vital capacity per cent to normal (FVC%), forced expiratory volume in the first second per cent to normal (FEV1%), and FEV1/FVC ratio. Forced vital capacity and FEV1 were analysed at the patients' bedsides on the day before surgery and were repeated on postoperative day 5, at discharge, and at 30 days postoperatively by the same respiratory physiotherapist, using a portable spirometer. All patients treated were with the same analgesic protocol administered in the first five postoperative days and were given daily physiotherapy until discharge.

Postoperative Complications

Postoperative complications were reported and defined as follows. (i) Postoperative wound infection: indicated by the presence of pus or an abscess, fever with tenderness of the wound, or a separation of the edges of the incision exposing the deeper tissues [12]. (ii) Bleeding: haemorrhage is present when operating field blood loss exceeds 600 mL/hour necessitating, among other measures, the intermittent application of packing, and when the chest drains pours out >300 mL/hour or 150 mL/hour blood for 2 hours postoperatively [13]. (iii) Lung atelectasis: referring to the collapse of small airways and alveoli with presence of lung densities on X-ray or CT scan. (iv) Pleural effusion: small to moderate in size; present within 1 - 2 days after surgery, not progressive, and not associated with respiratory symptoms [14].

Exclusion Criteria

Exclusion criteria were age >65 years; a reduced left ventricular function (ejection fraction <30%), as these patients have increased mortality and morbidity; redo, or emergency or high-risk CABG cases, to avoid complications unrelated to the planned surgical procedures as these patients usually need a prolonged postoperative intensive care unit (ICU) stay and mechanical ventilation; patients with chronic pulmonary disease (e.g., chronic obstructive pulmonary disease); patients with skeletal abnormalities of the chest causing pulmonary restrictions; and patients indicated for concomitant cardiac or non-cardiac surgery.

Statistical Analysis

Statistical analyses were performed with SPSS version 21 (IBM, Armonk, NY, USA). Categorical data are expressed as n (%). Continuous normally distributed data are expressed as mean ± standard deviation, while non-normally

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Table 1 Patient demographics.

Variable	Closed group (n=50)	Open group (n=50)	P-value
Mean ± SD age (yr)	61.7±7.4	58.6±5.3	0.538
Sex			
Female	11 (22)	13 (26)	0.641
Male	39 (78)	37 (74)	0.425
DM	28 (56)	26 (52)	0.688
Hypertension	28 (56)	24 (48)	0.423
Smoking	26 (52)	23 (46)	0.378
Hyperlipidaemia	20 (40)	28 (56)	0.465
Mean ± SD PFT			
FEV1%	94.2±4.4	91.5±4.7	0.004
FVC%	92.7±4.4	87.4±4.6	0.0001
FEV1/FVC	86.2±2.3	82.9±2.6	0.0001

All values are expressed as n (%) unless otherwise indicated.
Abbreviations: SD, standard deviation; DM, diabetes mellitus; PFT, pulmonary function test; FEV1%, forced expiratory volume in first second per cent; FVC%, forced vital capacity per cent; FEV1/FVC, difference between CP and OP group at 5 days and at discharge.

distributed data are expressed as median (range). Quantitative data were examined by the Kolmogorov–Smirnov test for normality of the data. The Student's *t*-test was used for continuous normally distributed data and the Mann–Whitney *U*-test for non-normally distributed data. Comparison of categorical data was done using the chi-square test or Fisher's exact test when appropriate. A one-sample *t*-test was used to compare the mean within the same group. Statistical significance was considered when the p-value was ≤0.05.

Results

The CP group consisted of 11 (22%) women and 39 (78%) men; the OP group consisted of 13 (26%) women and 37 (74%) men. There was no statistically significant difference in sex distribution between the groups. The mean age of patients in the CP group was 61.7±7.4 years versus 58.6 ± 5.3 years in the OP group (non-significant) (Table 1).

Preoperative Risk Factors

Risk factor data for both groups showed that there were no statistically significant differences between the two groups regarding the incidence of diabetes mellitus, hypertension, smoking, and hyperlipidaemia (Table 1).

Preoperative Evaluation

There were no statistically significant differences regarding pulmonary function parameters (FEV1%, FVC%, FEV1/FVC%) and arterial blood gases data between the two groups (Table 1).

Table 2 Intensive care unit evaluation.

Variable	Closed group	Open group	P-value
Mean ± SD ventilation time (hr)	5.5±2.8	8.1±3.8	0.0002
Median (range) length of ICU stay (d)	2.1 (0-2.3)	3 (0-4.2)	0.05
Mean ± SD length of hospital stay (d)	7.5±2.5	9.1±4.8	0.039

Abbreviations: SD, standard deviation; ICU, intensive care unit.

Intraoperative data

In the CP group, the mean cross-clamp time was 58.2 ± 15.4 minutes and entire bypass time was 93.6 ± 24.2 minutes versus 51.3 ± 14.9 and 82.01 ± 19.8 minutes, respectively, in the OP group. There was no statistically significant difference in the intra-operative data obtained from both groups ($p>0.05$).

Postoperative Evaluation

The postoperative evaluation showed that patients in the CP group had a statistically significant improvement in postoperative ventilation time and ICU stay and length of hospital stay compared with patients in the OP group (p=0.002, p=0.05, and p=0.039, respectively) (Table 2).

Postoperative Complications

Lung atelectasis and pleural effusion were significantly lower in patients in the CP group (n=1 [2%] and n=2 [4%], respectively) compared with those in the OP group (n=6 [12%] and n=9 [18%], respectively). However, there were no statistically significant differences regarding postoperative wound infection, bleeding, blood transfusion, use of intra-aortic balloon pump, and mortality (Table 3).

Table 3 Postoperative complications.

Variable	Closed group (n=50)	Open group (n=50)	P-value
Mean ± SD haemorrhage (mL)	321.3±151.9	463.7±317.1	0.005
Patients needing a blood transfusion	2 (4)	4 (8)	0.104
Wound infection	4 (8)	5 (10)	0.727
IABP	1 (2)	2 (4)	0.204
Mortality	0	0	0
Atelectasis	1 (2)	6 (12)	0.037
Pleural effusion	2 (4)	9 (18)	0.009

All values are expressed as n (%) unless otherwise indicated.
Abbreviations: SD, standard deviation; IABP, intra-aortic balloon pump.

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Table 4 Pre- and postoperative (day 5) pulmonary function tests (PFTs).

PFT	Preoperative	Postoperative	P-value
Closed group			
FEV1%	94.2±4.4	70.6±4.8	0.001
FVC%	92.7±4.4	70.1±4.7	0.001
FEV1%/FVC%	86.2±2.3	99.1±5.6	0.002
Open group			
FEV1%	91.5±4.7	53.04±4.6	0.001
FVC%	87.4±4.6	54.6±4.1	0.001
FEV1%/FVC%	82.9±2.6	97.2±4.4	0.001

All values are expressed as mean ± standard deviation.
Abbreviations: FEV1%, forced expiratory volume in second 1 per cent; FVC%, forced vital capacity per cent.

Comparison

The results of postoperative day 5 PFTs versus the corresponding preoperative values within each group showed a statistically significant decrease in predicted postoperative FEV1% and predicted FVC%, with a statistically significant increase in postoperative FEV1/FVC predicted in both groups (Table 4).

Statistical comparison of postoperative PFTs between both groups showed that predicted FEV1%, predicted FVC%, and predicted FEV1/FVC in patients in the CP group were significantly higher than the corresponding values in OP group on day 5 postoperatively, at discharge, and at day 30 postoperatively (Table 5).

Discussion

Maintenance of pleural integrity may affect patients' postoperative course, as demonstrated by our findings. In this way, closed pleural IMA harvesting may be particularly relevant to decreasing the early postoperative temporary respiratory impairment [15].

The postoperative evaluation showed that patients in the CP group had a statistically significant improvement in postoperative ventilation time and length of ICU and hospital stay than those in the OP group (p=0.002, p=0.05, and p=0.039, respectively). Interestingly, the literature is controversial regarding the effect of pleural integrity on the duration of mechanical ventilation after CABG (Table 6).

A reasonable explanation for the discrepancy between these results is that the pleurotomy may lead to the collection of blood in the pleural space, which may cause atelectasis of part of the lung. Also, this finding can be explained by disturbed alveolar stability due to the changing composition of the alveolar surfactant, which may be aggravated in patients with pleurotomy [16].

Blood loss was lower in patients in the CP group than in the OP group ($p>0.05$). Wimmer-Greinecker et al. [5] showed that there was a significantly higher blood loss in patients in their OP group than that in their CP group (608±58 mL vs 470±48 mL; p=0.027). Similar results were reported by Atay et al. [10] and Iskesen et al. [17]. With pleurotomy, blood will pass through the pleural cavity, reducing the chance of pericardial effusion and therefore tamponade. On the one hand, the patients may suffer from some degrees of pleural effusion rather than pericardial effusion. On the other hand, the entire pleura procedure may reduce the risk of postoperative pulmonary complications as there is no chance of pleural accumulation [18]. Also, impaired pleural integrity, traction upon the sternum, and damage to the thoracic wall during IMA harvesting may be the responsible factors [7].

Patients in the CP group had a significantly lower incidence of atelectasis compared with those in the OP group. Pleural effusion in patients in the CP group was significantly lower compared with those in the OP group (on day 5 postoperatively). Similar findings regarding the preferred

Table 5 Postoperative pulmonary function.

Pulmonary function	Group	5 d PO	Discharge	30 d PO	P1	P2	P3
FEV1%	Closed group	70.6±4.8	73.6±4.7	82.9±5.3	0.001	0.001	0.001
	Open group	53.04±4.6	58.7±5	72.3±4.9	0.001	0.001	0.001
p value		0.001	0.001	0.001			
FVC %	Closed group	70.1±4.7	72.6±4.4	81±5	0.001	0.001	0.001
	Open group	54.6±4.1	59.5±4.7	71.9±5.1	0.001	0.001	0.001
p value		0.001	0.001	0.001			
FEV1/FVC	Closed group	99.1±5.6	94.8±5.1	85.7±4.4	0.259	0.001	0.001
	Open group	97.2±4.4	93.5±4.3	86.3±3.3	0.001	0.001	0.001
p value		0.08	0.198	0.431			

Abbreviations: PO, postoperative; P1, comparison between 5 d PO and discharge; P2, differentiation between 5 d PO and 30 d PO; P3, differentiation between 30 d PO and discharge; FEV1/FVC, between closed and open group 5 d PO and discharge; FEV1%, forced expiratory volume in first second per cent; FVC%, forced vital capacity per cent.

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Table 6 Results of different studies regarding duration of mechanical ventilation.

Studies	Duration of mechanical ventilation
Ali et al. [19]	Insignificant difference between CP and OP groups (mean 20 hr in CP group vs 18 hr in OP group)
Goksin et al. [23]	A non-significant difference between both groups: 7.4±7.1 hr in CP group vs 7.2±3.8 hr in OP group
Bonacchi et al. [2]	Significantly higher in OP group compared with CP group: 6.2±2.9 hr in OP group vs 5.4±1.2 hr in CP group
Atay et al. [10]	Significantly lower in CP group compared with OP group (12.4±3.9 hr vs 14.03±10.7 hr)

Abbreviations: CP, closed pleura; OP, open pleura.

effect of pleural integrity on respiratory complications after CABG are widely described in the literature [19-21], where it was found that OP patients had a significantly higher incidence of left lung atelectasis (67.7% vs 45.2%; p=0.007) and an insignificant incidence of pleural effusion (42.5% vs 46.3%; p=0.66).

We hypothesise that the increase in atelectasis rate in patients in the OP group can be considered natural owing to the pressure of the haematoma in the pleural space, which can promote anatomical factors that influence atelectasis after CABG surgery. Patients with preserved pleural integrity (CP group) have a lower haematoma volume, and the incidence of the atelectasis is limited. Postoperative atelectasis may be due to pain-related breath restriction, which may cause cough restriction leading to mucus retention and atelectasis. Pleural effusion was increased in the OP group owing to the opening of the pleura itself, and drainage of the bleeding points of the mammary bed and mediastinum into the pleural cavity, which may cause minimal collection and irritation to the pleura with subsequent pleural effusion. The presence of the pleural tube may irritate the pleura and cause pleural effusion.

Analysis of PFT data revealed a statistically significant reduction in postoperative results compared with the preoperative results, regardless of the technique used. However, when the PFTs of the CP group were compared with those of the OP group at day 5 postoperatively, a statistically significant difference was found between the two groups ($p<0.05$) regarding FEV1% and FVC% in favour of the CP group.

Comparison of PFT results at day of discharge and at postoperative day 30 showed that FEV1% and FVC% were significantly higher in the CP group; there was no significant difference in FEV1/FVC ratio. Similar findings regarding changes in PFTs have been reported in the literature [5,6].

In contrast to these findings, confirming the better effect of pleural integrity on PFTs, Matsumoto et al. [22] showed that pleurotomy does not affect postoperative FEV1 at days 20 - 30 postoperatively. Also, the results of Iskesen et al. [17] are in disagreement with our results and showed that pleural preservation during coronary surgery did not have any beneficial effect on respiratory function. On day 7 postoperatively, FVC did not show any significant difference between groups (2.80±0.6 L in the CP group vs 2.75±0.5 L in the OP group; $p>0.05$). Also, there was no significant difference in postoperative FEV1% values (71.8±5.1% and 73.4±6.3%, respectively; $p>0.05$).

A reasonable explanation of these results is that the disturbed alveolar stability due to changing the composition of alveolar surfactant may be aggravated in patients with pleurotomy. The presence of an intercostal chest tube site in the OP group may add to the restrictive pattern of respiration in this group of patients.

Strengths and Limitations

The prospective nature of this study avoids the bias of retrospective studies as data evaluations were not only based on the patients' physical examinations, but also on analysis of chest X-rays, PFTs, and measurement of postoperative PFTs at various time intervals: 5 days postoperatively, at discharge, and at 30 days postoperatively, to detect changes with time. However, the study also has some limitations, which include a small number of patients and a small number of women, which may reduce the power of the conclusion. There were also insufficient data to analyse the relationship between clinical outcome and the financial cost to the hospital of each technique.

Conclusion

This study revealed better results of pleural preservation regarding postoperative PFTs and a lower rate of atelectasis and pleural effusion. Despite these results, the incidence of other postoperative complications, length of ICU stay, and length of total postoperative hospital stay was similar between groups.

Conflicts of Interest

There are no conflicts of interest to disclose.

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