ORIGINAL ARTICLE

Off-pump versus on-pump coronary artery bypass grafting in patients with chronic obstructive pulmonary disease

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Abstract

Objective: To compare the outcome of coronary artery bypass grafting with and without cardiopulmonary bypass in patients of chronic obstructive pulmonary disease.

Methods: The prospective randomised multicentre study was conducted in 2020 at Kafrelsheikh University Hospital, International Cardiac Centre and Alexandria New Medical Centre, Egypt.

Patients regardless of age and gender who had ischaemic heart disease and chronic obstructive pulmonary disease were enrolled, and randomised into on-pump procedure group 1 and off-pump procedure group II.

All patients were assessed preoperatively for pulmonary function tests and postoperatively for duration of mechanical ventilation, respiratory failure, pneumonia, atrial fibrillation, acute respiratory distress syndrome, pleural effusion, lung atelectasis, sternal dehiscence, intensive care unit stay and overall hospital stay. Data was analysed using SPSS ver 25 Armonk, NY: IBM Corp.; Released 2017.

Results: Of the 60 patients, 30(50%) were in each of the two groups. Overall, there were 20(33.3%) women and 40(66.6%) men with mean age 56.5±6.05 years. The mean duration of mechanical ventilation in group I was 12.07±5.18 minutes compared to 6.97±2.25 minutes in group II ($p<0.001$). The mean duration of stay in intensive care unit in group I was 4.17±1.64 days compared to 3.03±1.03 days in group II ($p<0.001$). The mean hospital stay was 7.40±1.90 days in group I and 5.93±1.17 days in group II ($p<0.001$). There was no significant difference between the groups regarding the frequency of respiratory failure, pneumonia, atrial fibrillation, acute respiratory distress syndrome, pleural effusion, lung atelectasis and sternal dehiscence ($p=1.000$)

Conclusion: Off-pump coronary artery bypass grafting was found to be efficient and had a faster postoperative course than on-pump procedure in patients with chronic obstructive pulmonary disease.

Keywords: Cardiopulmonary bypass, Atrial fibrillation, Respiration, Coronary artery, Lung, Chronic obstructive, Respiratory distress, Myocardial ischemia, Respiratory insufficiency, Pleural effusion, Pneumonia.

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Introduction

Chronic lung disease is a well-known risk factor for operative mortality from cardiac surgery, and, hence, it is included in Euro SCORE II.[1] Chronic obstructive pulmonary disease (COPD) is inflammation of the airway, alveoli and small blood vessels, which leads to remodelling at the level of small airways.[2]

A stud in 2017 defined COPD as persistent airflow limitation at the level of airways and / or alveoli due to precipitating material, like gasses or particles, leading to respiratory symptoms. It depends on spirometry findings; people who have forced expiratory volume in 1 second (FEV1)/FEV6 forced vital capacity (FVC) ratio <70% are considered COPD.[3]

Patients with COPD are at a higher risk for postoperative complications, such as respiratory failure, pneumonia, atrial fibrillation (AF) and acute respiratory distress syndrome (ARDS).[4]

The technique of on-pump coronary artery bypass (OPCAB) has progressed, and this may be more beneficial to patients with COPD by avoiding the side effects of cardiopulmonary bypass (CPB).[5]

Coronary artery bypass grafting (CABG) is the most frequent operation performed in the field of adult cardiac surgery, ad although OPCAB represents 15-30% of all CABG cases, there is still an active debate regarding its superiority.[6]

Despite the widely used CPB to perform CABG, off-pump CABG has become increasingly an area of interest because of the avoidance of the use of CPB and its associated systemic inflammatory response. Also, patients now have multiple morbid conditions, like diabetes, obesity, COPD and complex coronary artery disease (CCAD). A major benefit of CABG without CPB is that there is no aortic manipulation for aortic cannulation and no aortic cross-clamping.[7]

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The surgeons must be confident and choose their patients carefully. At the beginning of the learning curve, surgeons should leave out patients with left main coronary artery (LMCA) disease, poor left ventricular (LV) function, big heart size, complex coronary anatomy, and those with the involvement of lateral wall.[8]

Surgeons should be flexible to convert to CPB if needed in situations like arrhythmia, haemodynamic instability and myocardial ischaemia.

COPD was considered a contraindication to CABG, but with advances in anaesthesia and surgical techniques, COPD patients are undergoing CABG more frequently today.[9]

It is known that the prevalence of COPD in the general population is 11.7% and 16.1% to 53% in patients with ischaemic heart disease (IHD).[10]

The current study was planned to compare the on-pump and off-pump techniques for CABG in patients with COPD.

Patients and Methods

The prospective randomised multicentre study was conducted in 2020 at Kafrelsheikh University Hospital (KUH), International Cardiac Centre (ICC) and Alexandria New Medical Centre (ANMC), Egypt.

The study was approved by The Ethics Review Committees in the three centers:

1- Kafrelsheikh University Hospital, Egypt on 11 December 2019

2- International Cardiac Centre, Egypt on 17 November 2019

3- Alexandria New Medical Centre, Egypt on 15 November 2019

The study was registered in Pan African Clinical Trial Registry with identification number PACTR202302897543202

The sample size was calculated based on a previous study which investigated the immediate early pulmonary dysfunction in ischaemic heart disease patients undergoing off-pump versus on-pump coronary artery bypass grafting (CABG) to evaluate pulmonary dysfunction caused by cardio-pulmonary bypass (CPB) in patients undergoing on-pump CABG.[11] A power of 90% (β=0.10) was adopted to detect a standardized effect size in FEV1 reduction (primary outcome) of 1.524, and level of significance 5% (α error accepted =0.05). The minimum required sample size calculated was 22 patients per group making it 44 in two groups.[12,13] After adjustment for a dropout rate of 20%, the sample size was increased to 28 patients per group and a total of 56 patients.[14] GPower version 3.1.9.2[15] was also used for re-confirmation.of the sample size.

Convenience sampling technique was adopted and randomization was done by generating sequence using permuted block randomization technique with a varying block size. Allocation sequence/code was concealed from the person allocating the participants to the intervention arms using sealed opaque envelopes.

IHD patients having COPD regardless of age and gender were enrolled. Patients who had previous radiation to the chest, previous sternotomy, bilateral internal thoracic arteries harvesting, chronic kidney disease, emergency surgery, re-exploration for bleeding, and combined cardiac surgery were excluded.

After taking written informed consent from the participants, they were randomised into on-pump procedure group 1 and off-pump procedure group II. All patients were assessed preoperatively for pulmonary function tests, and postoperatively for mechanical ventilation, respiratory failure, pneumonia, atrial fibrillation (AF), ARDS, pleural effusion (PE), lung atelectasis and sternal dehiscence. Intensive care unit (ICU) stay and overall hospital stay periods were noted. Pulmonary function tests (PFTs) included FEV1, FVC, and FEV1/FVC ratio.

CABG in group I was done under general anaesthesia (GA) with an invasive arterial line and central venous access. Routine temperature monitoring and urinary catheter were used. Midline sternotomy was done in all cases. The left internal thoracic artery (ITA) was harvested. The saphenous vein was harvested simultaneously with sternotomy. After ITA harvesting, the pericardium was divided from the innominate vein superiorly to the diaphragm inferiorly. Retraction of the pericardium with sutures was done to improve the exposure of the right atrium and the ascending aorta. Aortic and atrial cannulation was done in the standard fashion. The cardioplegia cannula was inserted in the ascending aorta. CPB was started and after reaching full flow, ventilation was stopped. Target vessels could be visualised at this step and adventitia was marked using No. 15 blade. The aortic clamp was applied after the pump flow was turned down, and the bypass flow was returned to normal. Cold cardioplegia was administered into the aortic root in an antegrade fashion.

The distal anastomosis was done according to the surgeon's experience and preference. Then the proximal anastomosis was usually done on ascending aorta. After completion of all distal and proximal anastomoses, all grafts were checked for length, lie, twist and bleeding sites. The reperfusion time had to be 10 minutes for every 60 minutes of clamping time. The arterial blood gases (ABGs) were adjusted till the heart rhythm was regained and the patient's temperature was back to normal.

In group II, the patients went under GA with an invasive arterial line, central venous access and urinary catheter. The major characteristic of off-pump CABG is that it needs a hand-in-hand teamwork between the surgeon, the assistants and the anaesthesiologists to maintain haemodynamic stability before the graft anastomosis. Before manipulating the heart, the surgeon notified the anaesthesiologist to avoid sudden haemodynamic collapse by the administration of vasopressors.

The position of the table in Trendelenburg was the first important line of volume transfusion (autotransfusion) that provided haemodynamic stability and maintained blood pressure (BP) and it was better to avoid massive transfusions. It was very important to maintain normal body temperature. Regarding the heparinisation regimen, some surgeons gave a full dose of heparin, and others give a half-dose according to the surgeon's preference. After GA induction, invasive arterial and venous lines were inserted, and the patient was positioned in a supine position and draped as in on-pump routine. During left internal mammary artery (LIMA) harvesting, the saphenous vein was harvested at the same time. After completion of LIMA harvesting, the patient was heparinised and the pericardium was opened in an inverted T configuration and extended laterally to the left side to facilitate the exposure and displacement of the heart.

For the best position, several left pericardial stay sutures were taken while leaving the right pericardium without suspension to avoid compression of the right heart. Some surgeons intentionally opened the right pleura. Deep-stitch suture was taken into the pericardium at the point between the inferior vena cava and left pulmonary vein with due care to avoid injury to the underlying descending thoracic aorta, left lung, oesophagus, and inferior pulmonary vein. This suture was covered by a rubber tube to avoid laceration of the epicardium. If this stitch caused haemodynamic instability, LIMA-left anterior descending (LAD) artery anastomosis was made first to reperfuse the LAD so that the heart could tolerate further manipulation.

Instruments were used to position the heart through suction techniques, like octopus and starfish heart stabilisers because they did not affect the functional geometry of the heart as they depended on suction and not on compressing the heart. The stabiliser was fixed to the caudal aspect of the sternal retractor to the left side for anterior wall vessels. For lateral and inferior targets, the stabiliser was fixed towards the surgeon's side.

Using a silastic stitch with a blunt needle proximal to the site of anastomosis made it bloodless for better visualisation of the bites during anastomosis. A carbon dioxide (CO_2) blower was also used to facilitate better vision at each bite. Intracoronary shunts of different diameters were also available to control the bleeding, if needed. Then the distal anastomosis was done first for LIMA to LAD to allow myocardial revascularisation during the rest of the procedure to the LAD territory. After finishing distal anastomoses, proximal anastomoses were done by partial clamping of the aorta.

Postoperative evaluation of all patients included duration of mechanical ventilation, ICU stay, hospital stay, pneumonia, ARDS, PE, lung atelectasis and PFTs. The patients were followed up for 3 months post-surgery.

Data was analysed using SPSS ver 25 Armonk, NY: IBM Corp.; Released 2017.

Data was presented as mean ± standard deviation (SD), or as frequencies and percentages, as appropriate. Inter-group comparisons were done using Mann-Whitney U test. Qualitative variables were tested using Chi-square test. $P<0.05$ was considered statistically significant.

Results

Of the 60 patients, 40(66.6%) were treated at KUH, and 10(16.66%) each at ICC and ANMC. Overall, 30(50%) patients were in each of the two groups. There were 20(33.3%) women and 40(66.6%) men with mean age 56.5±6.05 years. The mean duration of mechanical ventilation in group I was 12.07±5.18 minutes compared to 6.97±2.25 minutes in group II ($p<0.001$). The mean duration of stay in ICU in group I was 4.17±1.64 days compared to 3.03±1.03 days in group II ($p<0.001$). The mean hospital stay was 7.40±1.90 days in group I and 5.93±1.17 days in group II ($p<0.001$) (Table 1, Figures 1-2). There was no significant difference between the groups regarding the frequency of respiratory failure, pneumonia, atrial fibrillation, acute respiratory distress syndrome, pleural effusion, lung atelectasis and sternal dehiscence ($p=1.000$). With regard to postoperative complications, there were 2(22.2%) cases of respiratory failure in group I and 1(11.1%) case in group II ($p>0.05$). Regarding pneumonia, there were 2(22.2%) cases in group 1, and 1(11.1%) case in group II ($p>0.05$). There were 3(33.3%) cases each in both the groups with AF ($p>0.05$). There was 1(11.1%) case of PE in group I and 2(22.2%) cases in group II ($p>0.05$)

Lung atelectasis was found in 3(33.3%) cases in group I and 2(22.2%) cases in group II ($p>0.05$).

There was one case of sternal dehiscence in group I and no case in group II ($p>0.05$) (Table 2, Figure 3).

Table-1: Comparison between the groups with respect to different parameters.

	On-pump (n = 30)	Off-pump (n = 30)	U	*p-value*
Duration of mechanical ventilation (hours)				
Min. – Max.	5.0 – 27.0	4.0 – 12.0	143.0*	<0.001*
Mean ± SD.	12.07 ± 5.18	6.97 ± 2.25		
Median (IQR)	10.50 (9 - 15)	6.50 (5 - 8)		
ICU stay				
Min. – Max.	3.0 – 11.0	2.0 – 6.0	218.0*	<0.001*
Mean ± SD.	4.17 ± 1.64	3.03 ± 1.03		
Median (IQR)	4.0 (3 - 4)	3.0 (2 - 3)		
Hospital stay				
Min. – Max.	6.0 – 16.0	4.0 – 9.0	187.0*	<0.001*
Mean ± SD.	7.40 ± 1.90	5.93 ± 1.17		
Median (IQR)	7.0 (6 - 8)	6.0 (5 - 6)		

ICU: Intensive care unit, SD: Standard deviation, IQR: Interquartile range.
U: Mann Whitney test
p: p value for comparing between the two studied groups
***: Statistically significant at p ≤ 0.05**

Table-2: Comparison between the groups with respect to to postoperative complications.

Postoperative complications	On-pump (n = 30) n (%)	Off-pump (n = 30) n (%)	χ^2	*p-value*
Respiratory failure	2 (6.7)	1 (3.3)	0.351	1.000
Pneumonia	2 (6.7)	1 (3.3)	0.351	1.000
Atrial fibrillation	3 (10.0)	3 (10.0)	0.000	1.000
ARDS	1 (3.3)	0 (0.0)	1.017	1.000
Pleural effusion	1 (3.3)	2 (6.7)	0.351	1.000
Lung atelectasis	3 (10.0)	2 (6.7)	0.218	1.000
Sternal dehiscence	1 (3.3)	0 (0.0)	1.017	1.000

ARDS: Acute respiratory distress syndrome
χ^2: Chi square test **FE: Fisher Exact**
p: p value for comparing between the two studied groups

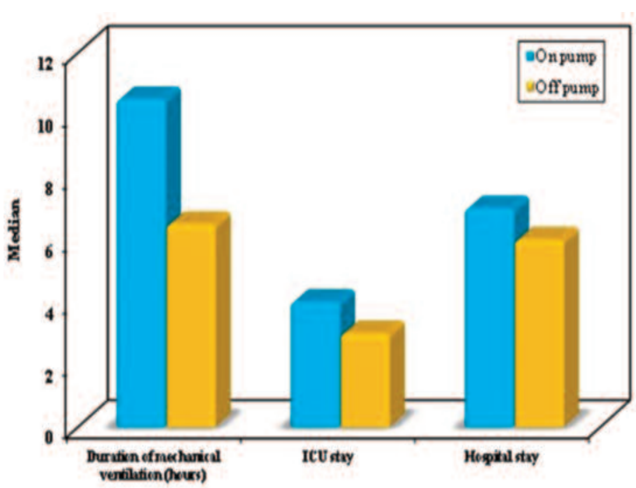

Figure 1: Comparison between the groups with respect to hospitalisation paramaters.
ICU: Intensive care unit.

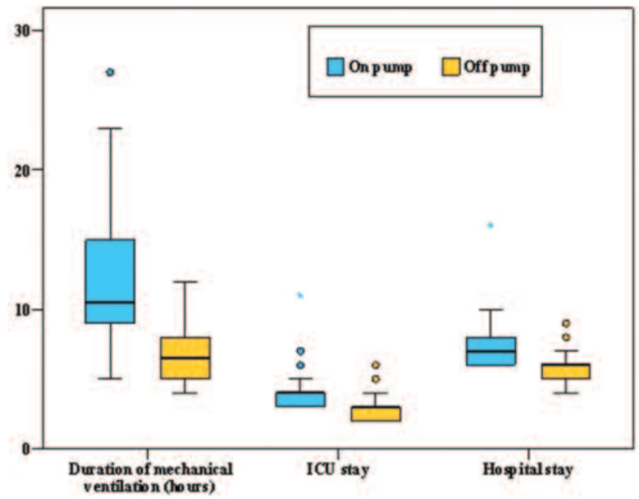

Figure 2: Comparison between the groups with respect to duration of mechanical ventilation (hours).
ICU: Intensive care unit.

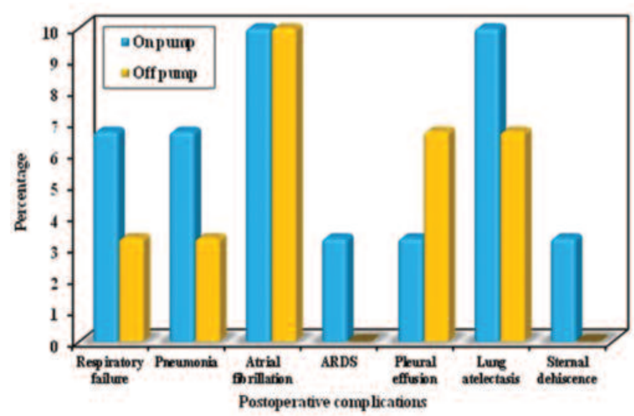

Figure 3: Comparison between the groups with respect to postoperative complications.
ARDS: Acute respiratory distress syndrome

Discussion

The current study found that off-pump CABG in COPD patients resulted in significantly shorter duration of mechanical ventilation, ICU stay, and hospital stay. Off-pump CABG in COPD patients showed no significant difference regarding postoperative complications compared to on-pump CABG regarding pneumonia. ARDS and lung atelectasis.

Literature review led to only earlier study that addressed the outcomes of on-pump versus off-pump CABG in COPD patients, which was done in 2016 on 40 patients to evaluate the degree of pulmonary dysfunction in on-pump and off-pump CABG, and reported that PFT values deteriorated significantly after coronary artery revascularisation with and without CPB, but to a significant value among those who had on-pump than off-pump surgeries. [11]

In 2018, a study comprising 42,570 patients in a very large registry compared morbidity and long-term survival in on-pump and off-pump CABG cases. It found that mortality was higher with off-pump CABG (33.4% vs. 29.6% at 10 years; p=0.002) in comparison with on-pump CABG. Also, off-pump CABG was associated with a higher incidence of under-revascularisation (15.7% vs. 8.8%; p < 0.001), which lead to late mortality (p=0.006), and higher rates of repeated revascularisation (15.4% vs. 14.0% at 10 years; p=0.048). Besides, there was no significant differences in the rate of cerebrovascular stroke, new dialysis, or myocardial infarction.[12] However, the data lacked subgroup analysis of COPD patients, which the current study did.

Also, a major cause for mortality was incomplete revascularisation which, we believe, depends significantly on the surgeon's experience.

Bakry et al. in 2018 compared the respiratory function after on-pump and off-pump CABG, and showed less frequency for lung injury slightly with off-pump in comparison to on-pump group in low-risk patients.[16]

Conclusion

Off-pump CABG was found to be more efficient than on-pump CABG in COPD patients with fewer complications.

Limitation: Both techniques could not be compared for long term graft patency.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

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