Does the off-pump coronary artery bypass grafting affect the outcome in ischemic cardiomyopathy?

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Abstract

Background: There is a concern to compare On- and Off-Pump coronary artery bypass grafting (CABG) regarding the benefits to the patient. The cardiopulmonary bypass (CPB) affects the left and the right ventricular functions. Is this the same with Off-Pump coronary artery bypass (OPCAB)?

Methods: Between January 2012 and December 2014, we revised 400 patients; 200 received on-pump CABG and 200 off-pump CABG (OPCAB). We included patients with ejection fraction (EF) of 35% or lower. The patients were followed up by preoperative echocardiography, intra-operative trans-esophageal echocardiography (TEE) and post-operative echocardiography: one week, 1 month, 3 months, 6 months, 1 year and 2 years after the CABG. The obtained results were compared statistically. We referred to the on-pump as group A and the off-pump as group B.

Results: The operative and postoperative data showed significant statistical differences between both groups; better in group B regarding the length of the operation, the intra-operative use of inotropic support, the use of intra-aortic balloon pump (IABP) intra- and post-operatively, the peri-operative myocardial infarction (MI), the post operative atrial fibrillation (AF), wound dehiscence, sternal wound infection, the incidence of strokes, renal impairment, chest infection and peripheral ischemia. The ICU stay and total hospital stay were longer in group A. The in-hospital mortality was more in group A. The LV function was more impaired in group A only in the first 3 months.

Conclusions: The complications of the on-pump CABG were more than the OPCAB. Accordingly, we recommend the OPCAB technique especially in patients with ischemic cardiomyopathy (ICM).

Keywords: Cardiomyopathy; Cardiopulmonary bypass; OPCAB

Abbreviations: AF, atrial fibrillation; BP, blood pressure; CPB, cardiopulmonary bypass; CABG, coronary artery bypass grafting; EF, ejection fraction; IABP, intra-aortic balloon pump; ICD, Implantable Cardioverter Defibrillator; ICM, ischemic cardiomyopathy; ICU, intensive care unit; IHD, ischemic heart disease; IMA, internal mammary artery; LAD, left anterior descending artery; LIMA, left internal mammary artery; LV, left ventricle; LVEF, left ventricular ejection fraction; MI, myocardial infarction; OPCAB, off-pump coronary artery bypass; RV, right ventricle; TEE, trans-esophageal echocardiography; TTFM, transit time flow meter; OM, oblique marginal artery; PL, postero-lateral artery; RCA, right coronary artery; PDA, posterior descending artery.

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1. Introduction

In CABG procedure, even with fair ventricular function and good revascularization, there is an impaired ventricular function (LV and RV) noticed after the surgery. The basic pre-operative ventricular function is definitely a predictor for the outcome. Yet even in normal values, impairment after good revascularization and uncomplicated surgery may occur [1]. The on-pump technique carries the risk of impaired ventricular function through the use of the CPB, the inflammatory reactions and micro-emboli, while in OPCAB the risk might occur due to the regional or focal ischemia during the procedure from the coronary occlusion, the tilt or twist of the heart or through the compression which affects the ventricular perfusion [1,2].

There is an immediate improvement in ventricular function in 21–65% of patients submitted for CABG [3–8]. This percentage depends on many predictors; previous MI, remodeling ICM, amount of viable myocardium and associated pathologies e.g. mitral regurgitation, ventricular aneurysm, aortic valve disease, coronary artery status, and the surgical procedure itself [9–18].

Some studies stated that even with no improvement in LV function after CABG, the future outcome is not bad, as the procedure of revascularization might protect against further myocardial deterioration or future MI. The recent imaging techniques can precisely assess the ventricular function and viability and hence can predict the outcome after surgery. The outcome and prognosis are by far much better than in medically treated myopathic patients [19–21].

Though the LVEF is a good predictor for the prognosis and outcome of surgery; yet some patients with no improvement in the LVEF have still better survival [22]. The LVEF being a predictor as well as a risk factor in the outcome of surgical revascularization, yet it is not a hinder against surgery especially with the new advents in the anesthesia, surgical techniques, medications, machines and ICU. Patients with low EF benefit either by a clear rise in the EF% or by better survival even without rise in the EF compared to medically treated patients [23]. In recent studies, there is a consensus that the EF rises slowly within the first 3 months, so the decision weather this patient will have a better EF or not after CABG is not an early one. Those patients who have no improvement in the EF must not be candidates for Implantable Cardioverter Defibrillator (ICD) except after 3 months of the surgery. It was noticed that those patients with EF 26–35% are more liable to postoperative improvement in EF and they were ineligible for ICD [24]. Regardless the concept of the ICD, it was noticed that the prognosis of surgical treatment in ischemic cardiomyopathic patients is more superior to medically treated patients and even PCI treated patients. This pushed many surgeons to search for the best technique to treat such patients [25].

Despite the fact that both techniques are convenient and safe for patients with low EF%, yet the cost of medical services and searching for more safety lead many to compare both procedures [26].

Many researchers studied the outcome of CABG in low EF% but all of them had variable bench mark for the EF% to be considered as low; in some studies it was ≤20% [26], in others it was ≤25% [27]. Most chose ≤35% [28] and few considered ≤40% as low EF [29]. In our study we included patients with EF% of ≤35%.

2. Patients and methods

Between January 2012 and December 2014, in a multicenter study, 400 patients of ischemic heart disease (IHD) with EF ≤35% were operated with CABG. 200 were operated using the CPB and 200 OPCAB without CPB. These patients were arranged into 2 groups; group A included the On-Pump cases and group B included the OPCAB cases.

2.1. Exclusion criteria for both groups

1. Recent MI.
2. Associated significant carotid artery disease.
3. Associated ventricular aneurysm.
4. Heart failure.
5. Recent or old strokes.
6. Femoral arterial block.
7. Incompletely re-vascularized patients. (Incomplete revascularization is the difference between the preoperatively estimated number of grafts to the actual number of grafted vessels). This might be due to: too small targets, diffusely diseased target or failure of exhibition of the target.
8. Bad LAD or no LIMA to LAD: if the LAD is a bad target, a vein or a radial artery was anastomosed to LAD or a small or ecstatic LAD.
9. Associated renal failure or impairment.
10. Associated valve lesions.
11. Redo cases.

The choice of either technique was based on the surgeon's preference and his experience and the 400 patients with low EF were selected retrospectively after applying the exclusion criteria. In all patients of both groups, we used the pedicled LIMA to an average sized LAD and vein grafts to the rest of the left and right systems. We did not use the radial artery or bilateral IMA. In all the patients, we inserted a femoral arterial line for the access of the IABP catheter if it was required.

2.2. On-pump cases

In all the cases, we used the standard midline skin incision and median full sternotomy, cannulating the ascending aorta excluding any area with heavy aortic atherosclerosis. The venous cannulation was via 2-staged atrial venous cannula 34F or 36F. Myocardial protection was done using ante-grade warm blood cardioplegia with systemic temperature drift without cooling. After aortic cross-clamping, the distal anastomosis was started with the right system first then continued with the left system using sequential technique. The last graft anastomosed was the LIMA to LAD. Then the proximals were anastomosed to the ascending aorta on beating heart. Assessment of the graft flow was done using the Transit Time Flow Meter (TTFM) calculating volumetric flow; using the Medi-Stim Flow-meter system referring to good flow graft if it was \( \geq 20 \text{ Ml/min} \).

2.3. OPCAB cases

We never cannulated the aorta or the atrium; the dose of heparin was adjusted to 150 U/kg and half dose protamine was given too. The cases on Plavix or Aspirin were not excluded in this group. The standard technique used was hanging pericardial stitches then posterior pericardial stitch infero-lateral to the left lower pulmonary veins to manipulate the heart during the OM or PL anastomosis. Soaked bulky gauze was used to raise the heart. We did not use apical (star fish) stabilizer. For regional cardiac stabilization; we used the Medtronic IV Octopus. Rubber silastic stitches with blunt needle were used to proximally and distally control the coronary vessel. The intracoronary shunts were not used in our procedure. We used humid CO2 blower and normal saline for better visualization and clearing of the field. The first distal graft was always the LIMA to LAD, followed by the OMs or PLs then the RAMUS and finally the DIAGONALS for the left system. The last distal was always the right system; either the RCA, PDA or marginal branches. We did not exclude intra-myocardial LAD even those cases requiring aggressive dissection for LAD exposure. In all the cases of both groups; the left system anastomosis was done sequentially if the calibers of the OMs, RAMUS or Diagonals were almost the same. We performed separate venous anastomosis if there was significant discrepancy in the size between the target coronaries.

3. Results

The demographic data in both groups did not show any statistically significant differences (Table 1) including age, gender and risk factors.

The intra-operative data (Table 2) revealed statistically significant difference in the length of the procedure in favor of the OPCAB; mostly due to the time taken for cannulation, recirculation, decannulation and hemostasis. The TEE

<table>
<thead>
<tr>
<th>Table 1 Preoperative demographic data.</th>
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<tbody>
<tr>
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<tr>
<td>Mean age (years)</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Family history</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Hypertension</td>
</tr>
<tr>
<td>Dyslipidemia</td>
</tr>
<tr>
<td>Smoking</td>
</tr>
<tr>
<td>Left main</td>
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<tr>
<td>EP%</td>
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</tbody>
</table>

SS = statistically significant, SI = statistically insignificant.
performed after closure of the sternum showed better EF% with P-value < 0.01 in both groups. In group B there were no intra-operative deaths while in group A 3 cases failed to survive due to severely impaired contractility. The conversion from OPCAB to On-Pump in group B occurred in 2 cases only and those cases survived during the one-year follow up with fair EF%. In group A, 13 cases had a stormy operative course mainly failure of many trials for weaning off bypass. Four of those cases died in the ICU, 1 in the first post-operative day and the other 3 cases within the first week post-operatively; due to severe pump failure. The peri-operative MI was also higher in group A than in group B; with an impact on some other data post-operatively e.g. the dose of inotropic support, the IABP insertion and the length of ICU as well as hospital stay. The incidence of intra-operative arrhythmias was higher in the On-Pump cases with statistical significance difference regarding the atrial fibrillation but with no significant difference in ventricular arrhythmias.

The post-operative data (Table 3) showed significant statistical differences in favor of the OPCAB, except in the incidence of ventricular arrhythmias, GIT complications, liver function, the late occurrence of heart failure, the late measurement of the EF% till the third month post-operatively and the need for the ICD implantation. The post-operative complications were also much higher in group A than B. The total cost of the health care in group A was significantly higher than B with almost 40% increase in the final billing. There were 2 late mortalities in group A within one year of hospital discharge due to intractable heart failure. One of these 2 patients had an ICD device while the other received no ICD and came in the ER arrested due to malignant arrhythmia. In group B, there was only one late mortality after 2 months of the operation. This patient was admitted to the CCU for almost one month and received an ICD.

4. Discussion

Although the CABG in low EF patients is risky, yet the outcome is much favorable than medically treated patients [30]. The use of the CPB carries many risks in normal EF and hence these risks are increased in low EF. In many studies there were unfavorable outcome and much more complications with the use of the heart lung machine in patients with low EF <35% [31,32].

The use of the CPB is safe and constitutes most of the sector of CABG procedures performed worldwide. However it is associated with many complications in high risk patients including those with low EF%, due to the instability of the BP, the non-pulsatile flow, the micro-emboli, the complement activation, the platelet aggregation and the higher incidence of bleeding as well as blood transfusion. Most of the studies comparing the outcome in both techniques had a limit between 20 and 35% EF. The mortality rate in these series was around 12% in the on-pump and around 3% in the off-pump [33–37].

Despite the results of many studies revealing clearly the differences in the outcome in both procedures referring to better outcome in the short term in OPCAB patients; some other studies failed to have these significant results as stated.
We have to admit that all the studies performed regarding these issues are not all focusing on the viability of the myocardium, and this may constitute a weak stone in all these studies. In fact there are some limitations in such field of study as the experience in the OPCAB procedure is so variable among individual surgeons, and sometimes the criticism directed to the technique may blow up any study from the start, honestly speaking, regarding the accuracy of the anastomosis and the longevity, and also the under-revascularization.

In our study, we selected the cases and there was no randomization, having exclusion criteria to unify the risk factors minimizing them only to the low EF%. The demographic data were peculiar in some aspects such as the low age, as this is the incidence in the Middle East region as well as the gender.

The operative findings were more or less concomitant with the other studies in this subject except for the length of the operation and this might be due to the long experience in the OPCAB. The number of grafts also was almost the same as we never under-revascularize even in big hearts or difficult targets, as many times we incised the right pleura and the pleuro-diaphragmatic reflection allowing the heart to come totally in the right thoracic cavity to perform easily the anastomoses of the OMs or the ramus artery.

To minimize the criticism towards the accuracy of the anastomosis, we measured the graft flow and patency using the Medi-Stim flow meter in all the cases, finding almost same flow pattern in both techniques.

There were no significant technical differences as regards the sequential or separate grafting as well as the RCA or PDA grafting. The inotropic support was higher in group A than B, which might be due to the global ischemia rather than the regional ischemia in the OPCAB. This also affected the process of weaning off bypass as well as the EF% intraoperatively in the on-pump cases leading eventually to more mortality intraoperatively in group A in comparison to group B (1.5% and 0%, respectively). The post operative AF was higher in on pump cases. The early outcome was much better in the OPCAB with better EF% in the first 3 months postoperatively.

The overall complications were less and the mortality was by far less in group B versus group A (4.5% versus 0.5%). All these results in our study proved the superiority of the OPCAB in cases of low EF <35%.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Post-operative data.</th>
<th>Group A (n = 200)</th>
<th>Group B (n = 200)</th>
<th>P-value.</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical ventilation (hours)</td>
<td>19.3 ± 7</td>
<td>11.5 ± 4.2</td>
<td>0.03</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>ICU stay (days)</td>
<td>7.1 ± 4.3</td>
<td>4.8 ± 2</td>
<td>0.023</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>16.5 ± 3.5</td>
<td>10 ± 3.5</td>
<td>0.031</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>ICU inotropes</td>
<td>112 (56%) &gt; 0.1μ</td>
<td>51 (25.5%) &gt; 0.1μ</td>
<td>0.04</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Intra- and post-operative IABP</td>
<td>19 (9.5%)</td>
<td>3 (1.5%)</td>
<td>0.012</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Postoperative AF</td>
<td>66 (33%)</td>
<td>24 (12%)</td>
<td>0.04</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Post-operative ventricular arrhythmia</td>
<td>22 (11%)</td>
<td>19 (9.5%)</td>
<td>0.7</td>
<td>SI</td>
<td></td>
</tr>
<tr>
<td>Chest infection</td>
<td>22 (11%)</td>
<td>9 (4.5%)</td>
<td>0.046</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Heart failure</td>
<td>31 (15.5%)</td>
<td>11 (5.5%)</td>
<td>0.03</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>1 (0.5%)</td>
<td>0 (0%)</td>
<td>0.0311</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Re-exploration</td>
<td>6 (3%)</td>
<td>1 (0.5%)</td>
<td>0.01</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Blood transfusion. (Units of packed RBCs)</td>
<td>5.2 ± 2.8</td>
<td>2.9 ± 1.4</td>
<td>0.023</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Renal impairment</td>
<td>14 (7%)</td>
<td>3 (1.5%)</td>
<td>0.02</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Hepatic impairment</td>
<td>7 (3.5%)</td>
<td>6 (3%)</td>
<td>0.8</td>
<td>SI</td>
<td></td>
</tr>
<tr>
<td>Wound infection/dehiscence</td>
<td>13 (6.5%)</td>
<td>5 (2.5%)</td>
<td>0.027</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>GIT complications</td>
<td>3 (1.5%)</td>
<td>4 (2%)</td>
<td>0.9</td>
<td>SI</td>
<td></td>
</tr>
<tr>
<td>EF% first week</td>
<td>23.1 ± 5.2</td>
<td>31.4 ± 11</td>
<td>&lt;0.001</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>EF% first month</td>
<td>27.3 ± 5</td>
<td>36.2 ± 8</td>
<td>&lt;0.003</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>EF% third month</td>
<td>28.2 ± 7.6</td>
<td>40.3 ± 9.5</td>
<td>&lt;0.002</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>EF% 6th month</td>
<td>39.7 ± 9.5</td>
<td>41 ± 11</td>
<td>0.6</td>
<td>SI</td>
<td></td>
</tr>
<tr>
<td>EF% after one year</td>
<td>40 ± 10</td>
<td>40.5 ± 11</td>
<td>0.6</td>
<td>SI</td>
<td></td>
</tr>
<tr>
<td>ICD implantation</td>
<td>3</td>
<td>2</td>
<td>0.66</td>
<td>SI</td>
<td></td>
</tr>
<tr>
<td>ICU mortality</td>
<td>4</td>
<td>0</td>
<td>0.0011</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>One-year mortality</td>
<td>2</td>
<td>1</td>
<td>0.02</td>
<td>SS</td>
<td></td>
</tr>
<tr>
<td>Late heart failure</td>
<td>19</td>
<td>17</td>
<td>0.06</td>
<td>SI</td>
<td></td>
</tr>
</tbody>
</table>

SS = statistically significant, SI = statistically insignificant.

by Attaran and his colleagues [38]. We have to admit that all the studies performed regarding these issues are not all focusing on the viability of the myocardium, and this may constitute a weak stone in all these studies [39].
5. Conclusions

It is much better to do CABG OFF-PUMP than performing it ON-PUMP in cases with bad LV function for patient safety and limiting the financial expenses.

Conflict of interest

None.

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