Section: Cardiovascular and Thoracic Surgery

Original Research Article

OFF-PUMP VERSUS ON-PUMP BEATING HEART VERSUS ON-PUMP ARRESTED HEART CORONARY ARTERY BYPASS GRAFTING. IS THERE ONE BEST OPTION? A COMPARATIVE STUDY

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Received *: 13/04/2025*
Received in revised form *: 28/05/2025*
Accepted *: 17/06/2025*

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DOI: 10.70034/ijmedph.2025.2.491

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2025; 15 (2); 2712-2715

ABSTRACT

Background: Coronary Artery Bypass Grafting (CABG) continues to remain as the gold standard treatment modality for coronary artery disease, when nonsurgical procedures are not a choice. The disease burden and the condition of the heart play a major role in the degree of revascularisation. Compared to conventional CABG with Cardiopulmonary Bypass, Off-pump CABG and On-Pump Beating Heart CABG have now been undertaken as alternatives.
Materials and Methods: This study aims to evaluate the outcome amongst different patients who underwent CABG, based on the CABG picked for them, at a tertiary care specialist hospital between May 2024 and May 2025; compared in terms of the duration of surgery, the degree of revascularisation, post-operative complications and outcomes including postoperative ECHOs and overall outcome and technical differences clinically.
Results: Of the 85 patients compared, there was a male preponderance amongst the patients. The mean age of the patients was 54 years, in the study population ranging between 38 to 72 years. Most patients under went off-pump CABG. Complications were more common in the patients undergoing on-pump beating as well as arrested heart CABG, however the grafts completeness was also high in these groups. It was noted that patients undergoing CABG with CPB support were sicker at presentation than in the off-pump CABG group.
Conclusion: Though not much comparison can be drawn to prove one method is superior to the rest due to variation in patient population and presentation, it is concluded that the choice of surgery much be patient-centric, tailored to the condition and disease burden of the patient for optimal outcome. Though complications recorded were high in the on-pump group than the off-pump group, the patient condition was also sicker in these groups, reinforcing the need for personalised approach than setting one best method. Long-term follow-up studies with matched population may help shine better light on the comparison as well in the future.
Keywords: On-pump beating heart CABG, On-pump arrested heart CABG, Off-pump CABG, Coronary artery disease.

INTRODUCTION

Since the first few and successful attempts at Coronary Artery Bypass Grafting (CABG) in the early 1960s,[1] there has been a huge curve of modifications and improvement in the procedure to better the outcome as well as the surgeon's comfort. CABG with Cardiopulmonary Bypass (CPB) was initially adopted as the mainstay, making this the conventional procedure during the late 1960s,[2] due to it aiding ease of surgery in the form of a blood-less and motion-less filed, augmenting anastomosis

construction.[3] However, with the potential complications and hazards of CPB, in terms of hemodilution, anticoagulant use, coagulopathy, systemic inflammation and activation of platelets, blood constituents and enzymes contributing to a myriad of unfavourable outcomes, including end-organ damage, micro-embolism and possibility of organ system failure in select susceptible individuals raising the morbidity and mortality.[2] With the notion of possibly avoiding these potential complications, the attempt to avoid CPB use was made with the introduction of Off-Pump CABG (OPCAB).[4]

Unlike conventional CABG using both CPB and cardiac arrest, and OPCABG which doesn't, over the last 2 decades has evolved On-pump Beating Heart (OPBH) CABG – an intermediate procedure between the two, that is gaining popularity of late in clinical use,[5] more in high-risk surgeries or in cases with poor left ventricular function.[5] Even though CABG as a treatment has remained a gold standard treatment for coronary artery disease,[6] irrespective of the disease load, especially when medical or non-surgical therapy has failed or is not an option, there is no comparison of the procedural clinical differences or the outcomes of surgery.

MATERIALS AND METHODS

The primary aim of this study was to compare the outcome of surgery amongst patients for each of the type of CABG – conventional on-pump, on-pump beating heart and off-pump, in terms of post-operative duration of supportive care and ICU stay, complications, other system morbidity and mortality as well as procedural acumen in the form of completeness of revascularisation with respect to disease burden. The secondary objective was to compare the technical differences during and post-surgery as blood loss, duration of surgery, additional procedures like endarterectomy, dosage of anticoagulation as well as need for transfusions between the three groups.

This observational study was conducted in the Department of Cardiac Surgery in a tertiary care superspeciality hospital in Tamil Nadu, during a period of 1 year between May 2024 and May 2025. 85 patients underwent CABG during this period and all surgeries were performed by a single consultant in the same institute with the same equipment, negating operator technical bias. All surgeries were performed via a midline sternotomy. The Medtronic Octopus cardiac stabiliser was used to stabilise the heart for distal anastomosis and intracoronary shunts were used to maintain target vessel patency and distal flow during anastomosis.

All patients who underwent CABG during the study period were included in their respective groups, irrespective of their existing disease burden, evaluated and operated on within 1 month of presentation at the most and within a maximum of 6 months of coronary angiogram (CAG) demonstrating the disease and lesions being done; with the exception of patients having a co-existing valvular pathology that needed to be surgically addressed. Patients who underwent only CABG in the absence of any other intracardiac procedure were excluded from the study. Patients requiring endarterectomy for completeness of revascularisation were included in their respective comparative surgical groups. Decision of the grafts were made by the operating surgeon, based on the CAG evidence. LIMA was harvested in cases which showed good LIMA from on the preoperative CAG, most commonly grafted to the LAD. Saphenous vein grafts from one or both lower limbs were used as conduit for other grafts.

The study population was divided into 3: (A) Patients who underwent Off-pump CABG (OPCABG), (B) Patients who underwent On-Pump Beating Heart CABG (OPBH CABG) and (C) Patients who underwent On-Pump Arrested Heart CABG (OPAH CABG) or conventional CABG.

RESULTS

Of the 85 patients operated, 62 patients fell under group A, 17 patients under group B and 6 patients under group C.

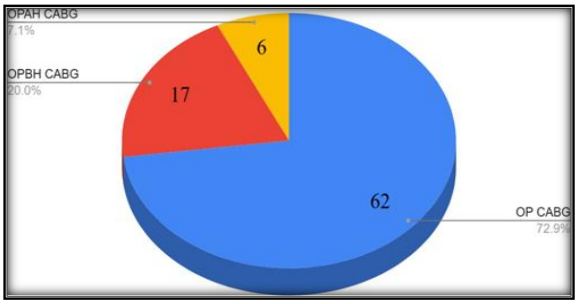

Figure 1: Division of Patients

There was a male preponderance amongst the patients undergoing CABG.

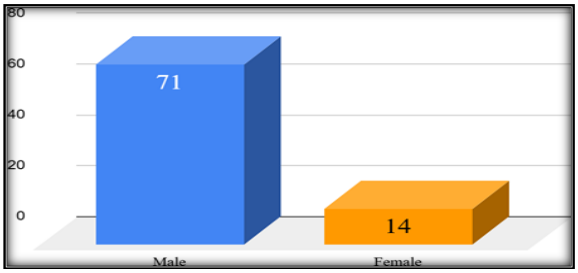

Figure 2: Gender Distribution

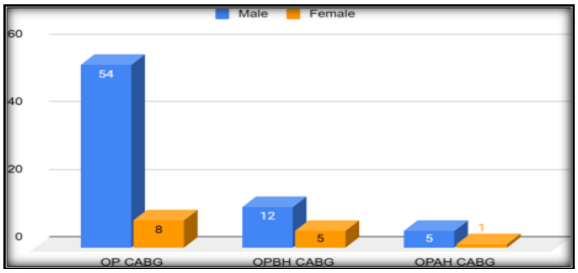

Figure 3: Groupwise Gender Distribution

The mean age of the study population was 54 years, with the patients being between 38 to 72 years, the maximum patient load being in the 50 to 60 years age group.

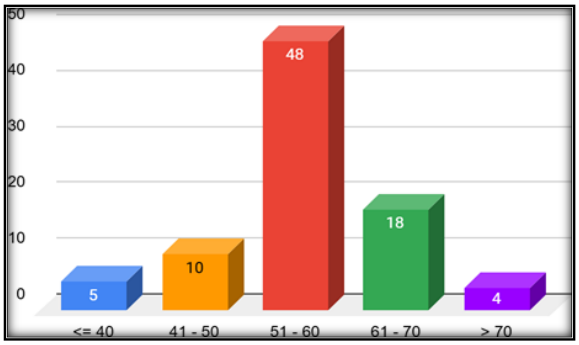

Figure 4: Age Distribution

The duration of surgery, duration of ICU stay, duration of elective mechanical ventilation, duration of post-operative inotrope support, duration of retaining surgical drains, day of mobilisation and overall duration of hospital stay were compared.

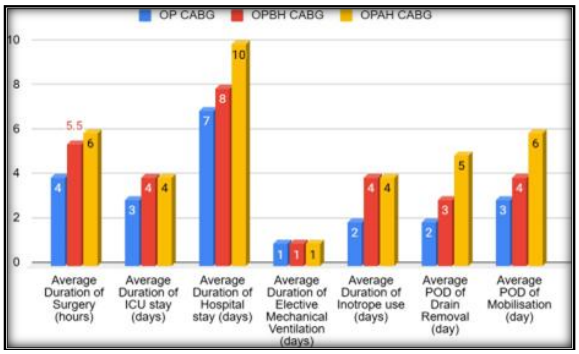

Figure 5: Post-op Comparison

Completeness of revascularisation in terms of the number of grafts anastomosed was compared between the 3 groups.

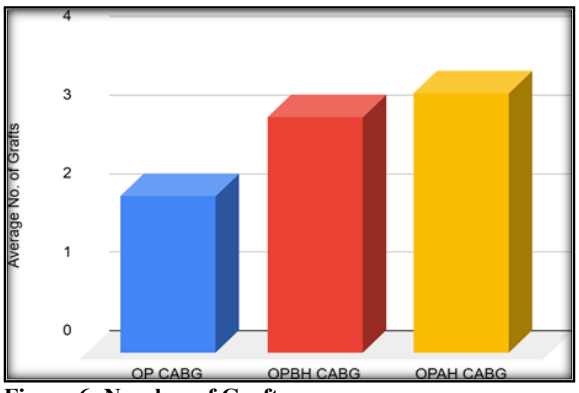

Figure 6: Number of Grafts

Intraoperative and post operative complications – mainly intraoperative blood loss, postoperative total drain output, average number of total blood transfusions both in the intra and post operative period together, perioperative Myocardial Ischemia in the form of ST changes and immediate post operative rhythm disturbances in the form atrial or ventricular fibrillations were compared. Postoperative systemic complications like acute respiratory distress syndrome due to pump-lung syndrome, acute kidney injury, low cardiac output syndrome and overall mortality were also compared. It was noted that both intraoperative and postoperative complications were highest in the OPAH CABG group followed by the OPBH CABG group. Least complications were recorded in the OP CABG group.

Intraoperative conversion from OP CABG to on-pump CABG was seen in 5 cases, 2 requiring to proceed with OPAH CABG and the remaining being completed on OPBH CABG, due to profound fall in blood pressures during positioning and the need for posterior grafts, where the vessels were very posterior.

Overall mortality from the study population was 5 patients; 2 from the OPAH CABG, 1 from the OPBH CABG group and 2 from the OP CABG group. All patients except 1 in the OP CABG group expired within 48 hours of surgery, the cause of death being low cardiac output syndrome. 1 patient from the OP CABG group expired on post-operative day 6 from aspiration.

DISCUSSION

The patients were pre-operatively electively decided on the type of surgery they would be receiving based on the disease burden – the number of vessels affected and the number of grafts planned as well as the degree of occlusion if the left main coronary artery was diseased. Preoperative ECHO also played a role in deciding the type of surgery for the patient, in terms of the function of the left ventricle and the pre-operative ejection fraction. It was noted that though the recorded presentation and symptomatology were mostly similar for all patients, irrespective of the disease burden, being primarily chest pain, associated with shortness of breath and sweating with some patients having palpitation, the duration, intensity and frequency were more in patients with higher disease status.

It was noted that the duration of surgery was relatively shorter among patients in group A, but longest in patients of group C. Intraoperative blood loss appeared to be higher in patients of group A but fairly similar in patients of groups B and C. However, the blood transfusion rate was grossly similar in all 3 groups. Though the average duration of elective ventilation was similar in all 3 groups, it was noted that the need of post extubation non-invasive ventilatory support was predominantly needed in patients of group B and C, relatively more in group C.

There was a higher rate of post-operative rhythm disturbances in groups B and C as well. Patients of groups B and C had to retain their surgical drains longer as well as took more time to be mobilised.

Other system complications were more in patients of groups B and C.

With respect to the completeness of revascularisation, it was noted that maximum vessels were grafted in patients of group C, however the number of patients in group A receiving lesser number of grafts than was planned pre-operatively was high, with only significant lesions being primarily addressed in this group. ST changes and evidence of perioperative myocardial infarction were also high in group A. The overall all-cause mortality however was similar in all 3 groups.

CONCLUSION

Our study noted that patients undergoing OP CABG had a shorter operating time, lesser bleeding complications, earlier drain removal, earlier mobilisation decreased need for post extubation non-invasive ventilatory support and lesser post-operative rhythm disturbances compared to the other groups. The main contributing factor for increasing the surgery duration was the process of going on and coming off bypass, further aggravated by arresting the heart and furthermore supporting the heart on pump. Also, the use of full dose of heparin to maintain ACT during the pump run contributed to increased bleeding complications intra and post-op, adding to the increased drain output, resulting in longer duration of retaining the drain as well as delayed mobilisation.

The increased volume from prime, as well as activation of inflammatory mediators as a result of cardiopulmonary bypass, majorly contributed to other system post-operative complications such as acute respiratory distress syndrome, acute kidney injury, pump psychosis; the likes of which were not present in patients undergoing OP CABG. These contributed to the overall mortality.

The major factor for the decision on the type of surgery however depended on the disease burden of the patients. It was routinely elected to proceed with CPB support in patients with pre-operative dilated left ventricle, poor EF, presence of pulmonary hypertension or when difficulty in off-loading the heart was anticipated. Patients with a significant left main coronary artery disease of >50% stenosis were also routinely operated with CPB support. Patients with a dilated heart, when positioning of the heart especially for posterior grafts would cause profound threatening hypotension were electively decided to be planned for on-pump arrested heart CABG. Stable left ventricle with adequate systolic and diastolic function, without pulmonary hypertension, without anticipated hypotension or complications during positioning for grafting, with adequate EF were the cases that were planned for off-pump CABG.

In conclusion, it was observed that the patients who underwent CABG with CPB support, either beating or arrested heart had poorer pre-operative cardiac function and worse disease load compared to the patients who underwent OP CABG. These patients also had more significant stenoses or left main disease and coexisting poor EF, dilated left ventricle or pulmonary hypertension. Hence, due to the varied presentation and disease burden of patients, it is essential to choose the type of surgery suited for their particular condition, tailored for each patient to improve and provide the best outcome possible. We cannot conclude the superiority of one type of surgery over the other as each has its advantages and disadvantages and we have to choose what is suitable to the patient's presentation for the best outcome possible.

Limitations

Our study was a single centre, single operator study, which though negated technical bias, could not be matched adequately for all three groups, resulting in more patient population in one group than the others, due to patient presentation and demographics. Our study has been conducted for a duration of 1 year only and follow-up data of patients were not compared in this study. Though we are unable to conclude superiority of one type of surgery over the others due to patient factors, it may be beneficial for future studies with longer duration and more sample population, also taking into account patient follow-up to have a more matched study population for clearer comparison.

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