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Original Research Article

On Pump Beating Heart CABG: an Acceptable Trade Off?

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Abstract:

Introduction: On-pump beating heart coronary surgery is a combination of normal on-pump surgery and the OPCAB approach. The lack of cardioplegic arrest, together with the hemodynamic stability provided by substantial cardiac manipulation, are thought to be the most significant advantages of this approach. The purpose of this research is to investigate CABG procedures, their respective benefits and drawbacks, and their impact on the end result, with a focus on the on pump beating heart operation

Aims and Objectives: (1) To assess the relative merits and demerits of different techniques of myocardial revascularization, with reference to in- hospital mortality andmorbidity associated with either procedure. (2) To find out whether on pump beating heart CABG is to be considered anacceptable tradeoff between cardioplegic and OPCAB procedures

Results: The 91 patients included in this study, were chosen in a manner as to allow equitable distribution among the three groups as per mortality risk using theadditive EUROSCORE.

The choice of procedure was at the discretion of the operating surgeon based on severity of disease, co-morbidities and peroperative findings. A total of 4 cases required conversion to the on pump beating heart procedure due to intraoperative haemodynamic instability so that complete revascularization could be performed. None of the cases required that grafting be abandoned due to intraoperative haemodynamic instability in the OPCAB group. A LIMA to LAD or D1 was routinely attempted in all cases. Cases with poor flow in LAD received RSVG. Three cases received a LIMA-radial Y-graft to D1. No significant difference in operating time was found in the three groups i.e OPCAB, On pump/beating, On pump/Arrest

Conclusion: Both OPCAB and on-pump CABG with cardioplegic arrest have great short-term outcomes in terms of mortality/morbidity. There was no significant difference in the number of grafts obtained between the three groups. The on-pump group required considerably more transfusions. The on pump groups showed greater post-operative drainage and lower mean hemoglobin levels in the immediate post-operative time. During the post-operative period, the on pump groups needed considerably more ionotropes.

Introduction

For patients needing conventional myocardial revascularization, cardiopulmonary bypass (CPB) with aortic cross-clamping and cardioplegic arrest remains the preferred approach. This procedure, which is used consistently across the globe to conduct conventional coronary artery bypass grafting (CABG), is nevertheless associated with a number of complications, the most of which are related to the use of aortic cross-clamping, cardioplegic cardiac arrest, and CPB. Many efforts have been made over the past two decades to limit the occurrence of significant intraoperative and postoperative problems associated to the surgery. [1,2] The off-pump coronary artery bypass grafting (OPCAB) approach was created in the 1990s to minimize the use of CPB, aortic cross-clamping, and cardioplegic arrest, with the express goal of lowering mortality and morbidity in high-risk and low-risk patients. [3] Unfortunately, the OPCAB technique can cause episodes of transitory hemodynamic instability during the extensive surgical manipulation and heart displacement required to perform multiple distal anastomoses, which can lead to secondary critical low coronary artery diastolic blood flow, severe complications, or death. [4,5,6] On-pump beating heart coronary surgery is a combination of normal on-pump surgery and the OPCAB approach.

The lack of cardioplegic arrest, together with the hemodynamic stability provided by substantial cardiac manipulation, are thought to be the most significant advantages of this approach. [7] The purpose of this research is to investigate CABG procedures, their respective benefits and drawbacks, and their impact on the end result, with a focus on the on pump beating heart operation. [8]

Aims and Objectives

1. To assess the relative merits and demerits of different techniques of myocardial revascularization, with reference to in- hospital mortality and morbidity associated with either procedure
2. To find out whether on pump beating heart CABG is to be considered an acceptable tradeoff between cardioplegic and OPCAB procedures

Materials and Methods

Study Design and Patients

Between December 2009 and December 2011, 91 patients undergoing CABG surgery at a single hospital were recruited prospectively and, after giving informed permission, were randomized post operatively into three groups after their expected mortality was calculated using the additive EUROSCORE. Indications for CABG surgery were determined by the operating cardiac surgeon based on co morbid variables and intraoperative results.

The trial's exclusion criteria included emergency surgery (requiring urgent surgery), concurrent major cardiac operations, and reoperation. All patients will be medically optimized prior to surgery after undergoing a preoperative cardiac examination that includes a chest X-ray, an ECG, and a routine coronary angiography.

Patients who presented with significant chest discomfort and/or reduced cardiac output were treated right away with anti-platelet medications, intravenous heparin or nitroglycerin infusion, and/or inotropic medicines (Dobutamine, Noradrenaline), depending on hemodynamic stability. Patients were prepped for surgery using standard CABG procedures, and an intraoperative trans-esophageal echocardiography was conducted. Patients were operated on utilizing traditional CPB, OPCAB, or pump beating heart techniques as determined by the operating surgeons to be the best option for each individual patient. The Ethics Board authorized the research.

Surgical Procedure

In all cases, a median sternotomy was done. Beating-heart surgery was carried out in a uniform manner. In brief, three retraction sutures were put in the posterior pericardium, followed by the implantation of a commercially available tissue stabilizer. To establish hemostasis following arteriotomy, a 4/0 circumferential prolene suture was placed to the target artery proximal to the anastomotic site. All anastomoses were created using a continuous-suture method and monofilament sutures sized 7-0 or 8-0.

CABG surgery with CPB and cardiac arrest was conducted in a systematic manner, including ascending aortic cannulation and 2-stage right atrial venous cannulation. The mean arterial pressure goal was established at 60 mm Hg during CPB, and the body temperature was permitted to drop to a minimum of 32°C. Unless otherwise specified, intermittent cold-blood cardioplegia (1:4 blood to crystalloid with a maximum K+ concentration of 22 mEq/L) was administered antegrade via the aortic root. In the on-pump beating heart group, the technique included ascending aortic cannulation and right atrial 2-stage venous cannulation. The mean arterial pressure goal was established at 60 mm Hg during CPB, and the body temperature was maintained normal. The choice of conduits and the creation of composite grafts in either the CPB or beating-heart techniques was dependent on surgeon choices rather than defined criteria. Arterial conduits were extracted with little damage (nonskeletonized internal mammary artery) and were all treated with a Papaverine solution or sodium nitroprusside.

Heparin was administered at a dosage of 300 IU/kg in the CPB group to reach a goal activated clotting time of >450 seconds, compared to 100 IU/kg in the beating-heart group. After the anastomosis was completed, both groups were given protamine sulfate to counteract the effects of heparin and restore the activated clotting time to preoperative values. Other than a nonhemic prime, retransfusion of the whole contents of the oxygenator at the conclusion of CPB, and acceptance of normovolemic anemia, no specific blood conservation measures were applied. Nonhemic volume expanders were commonly utilized postoperatively.

Postoperative Management

All patients undergoing postoperative cardiac surgery were sent to a cardiovascular critical care unit (ICU). Before being extubated and transferred to the intermediate care unit, each patient had to satisfy certain requirements. Each patient's requirement for a perioperative blood-product transfusion was assessed individually. There was no strict transfusion trigger for the use of homologous blood products; nonetheless, patients were generally not transfused until serum hemoglobin reached 100 mg/dL, unless they were clinically regarded at danger of impaired oxygen supply. Overall transfusion rates for blood products

provided intraoperatively and postoperatively were recorded.

This study did not involve preoperative transfusions. Similarly, patients were not routinely moved from the ICU if they were clinically assessed to be at risk for decreasing oxygen supply.

Patients who had been discharged were moved to a general-care ward under the supervision of the same staff. All patients were constantly observed for a minimum of 48 hours.

Unless hypotensive (systolic blood pressure 90 mm Hg), all patients received intravenous nitroglycerin infusions (0.1 to 8 g kg1 min1) for the first 24 hours. For a period of 3 to 6 months, all patients receiving a radial artery transplant were taken oral diltiazem commencing on day 1 following surgery. Other daily drugs included aspirin and the restart of cholesterol-lowering agents, -blockers, and ACE inhibitors if needed.

A 12-lead ECG was taken before the procedure, 2 hours later, and whenever clinically required. New Q waves (0.04 ms) in at least two leads or ECG ST Alterations associated with substantial creatine kinase-MB enzyme release were used as ECG criteria for perioperative myocardial infarction.

Results and Analysis

In this study a total of 91 patients were included.

The patients included were operated upon by three surgeons

The procedure (OPCAB/ on pump beating heart/ on pump with cardioplegia) carried out upon each patient depended upon the following:

1. Associated co morbidities
2. Surgeons comfort and discretion
3. Peroperative findings

Patients operated on emergent basis were not included in this study.

Patients with previous history of cardiac surgery or associated cardiac defects were also excluded

All patients underwent standard investigation protocols prior to CABG and were medically stabilized prior to surgery

Pre-operative Demographic Profile:

The 91 patients included in this study, were chosen in a manner as to allow equitable distribution among the three groups as per mortality risk using the additive EUROSCORE.

Table 1: No of Patients

OPCAB	On Pump beating	On pump with arrest	Total
31	30	30	91

Table 2: Age Distribution

	OPCAB	On Pump /Beating	On Pump/arrest
Age(Yrs)	58.53+6.72	59.3+7.4	57.6+5.6

Table 3: Sex (M: F)

OPCAB	On Pump/ Beating	On Pump / Arrest
31:2	30:1	30:2

Table 4: History of MI

OPCAB	On Pump/Beating	On Pump/Arrest
21	19	18

All patients with H/O MI that were included wereoperated upon at least weeks following the episode and were medicallyoptimized prior to surgery.

Table 5: History of Diabetes

OPCAB	On Pump/Beating	On Pump/Arrest
16	14	12

Strict pre-operative sugar control was achieved in allpoorly controlled diabetics on OHAs using regular insulin. Perop euglycemia was maintained using Human Actrapid via infusion pump with 2 hrly monitoring.

Table 6: Obesity

OPCAB	On Pump/Beating	On Pump/Arrest
3	3	4

Determined using BMI. Patients with BMI>40 were categorizedas Class 3 obese.

Table 7: History of COPD

OPCAB	On Pump/Beating	On Pump/Arrest
8	6	5

All patients undergoing CABG were evaluated using PFT. Patients with history or evidence of COPD were medically optimized prior tosurgery.

Table 8: Renal Dysfunction

OPCAB	On Pump/Beating	On Pump/Arrest
3	2	1

As evidenced by borderline raised creatinine levelsbut with adequate urine output and no indications for pre-op dialysis.

Table 9: Pre op Ejection Fraction

OPCAB	On Pump/Beating	On Pump/Arrest
40.3+4.29	41.4+5.3	42.8+4.8

Pre-operative ejection fraction was assessed by echocardiography in all cases and regional wall motion abnormalities documented.

Table 10: Pre op Angina

Angina	OPCAB	On Pump/Beating	On Pump/Arrest
Class1	0	0	0
Class2	20	21	19
Class3	9	6	7
Class4	2	3	4

Figure 1:

Table 11: No of Angiographically Diseased Vessels

Vessels involved	OPCAB	On Pump/Beating	On Pump/Arrest
Single vessel	1	1	0
Double vessel	13	10	11
Triple vessel	15	17	18
Four vessel	2	2	3

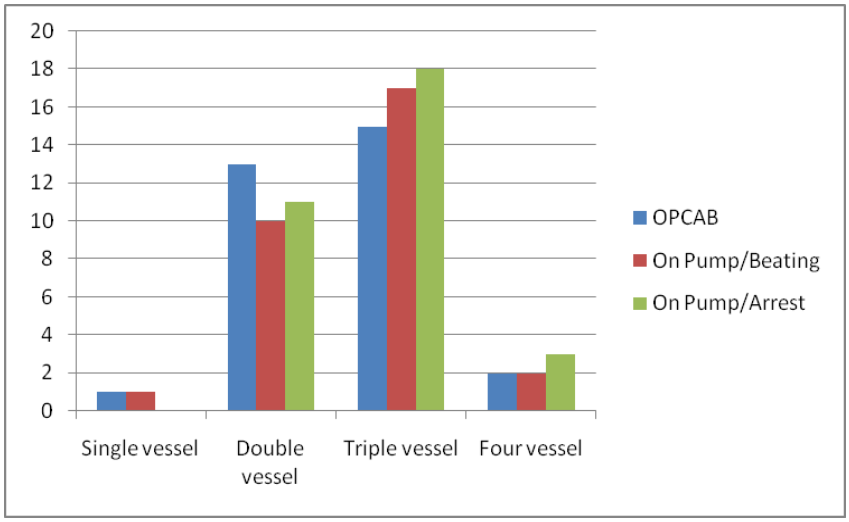

Figure 2:

Table 12: Risk Stratification

EUROSCORE	OPCAB	On Pump/Beating	On Pump/Arrest
0-2	5	3	3
3-5	22	25	23
>6	4	3	4

The risk of mortality following CABG was calculated using theAdditive EUROSCORE and the 91 patients that were chosen for inclusion in this study three were equitably distributed among the three groups.

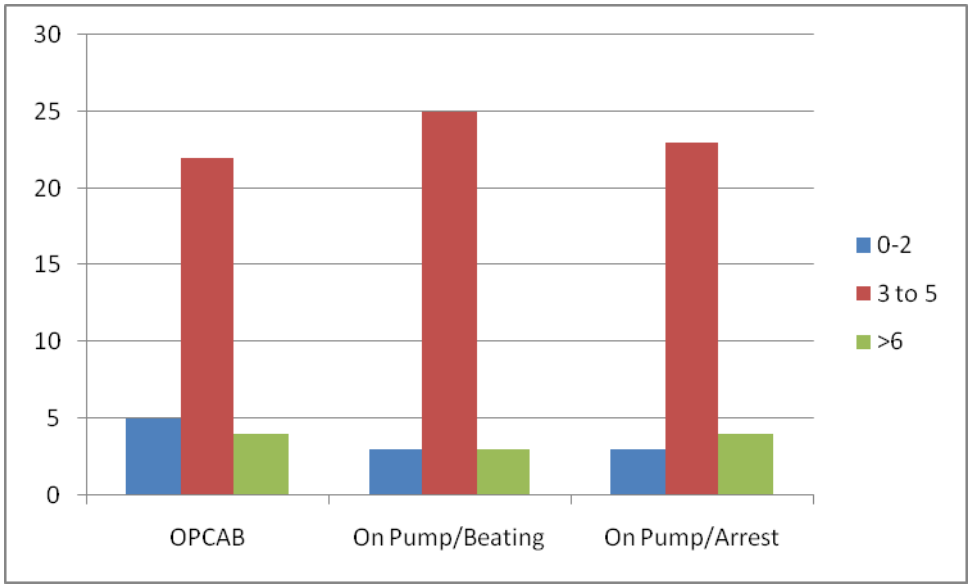

Figure 3:

Table 13: Surgical Technique

	OPCAB	On Pump/Beating	On Pump/Arrest
Surgeon1	21	3	8
Surgeon2	7	15	7
Surgeon3	3	12	15

All patients included in this study were operated upon by 3 surgeons who were well experienced in all three techniques of myocardial revascularization. The choice of procedure was at the discretion of the operating surgeon based on severity of disease , co-morbidities and peroperativefindings.

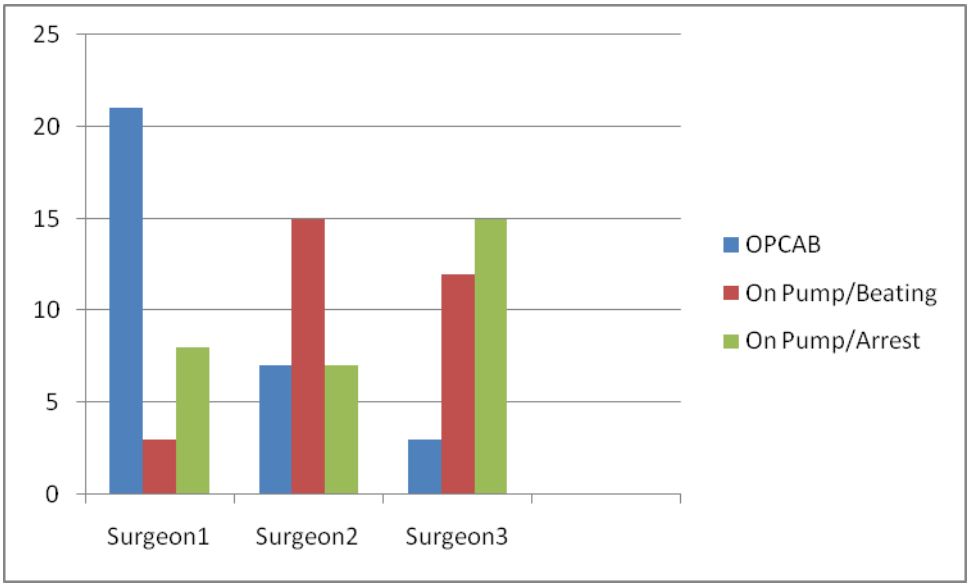

Figure 4:

Table 13: No of Grafts

No of Grafts	OPCAB	On Pump/Beating	On Pump/Arrest
one	1 (3.2%)	0	0
two	12 (38.7%)	14 (46.7%)	11 (36.7%)
three	15 (48.3%)	15 (50%)	17 (56.7%)
four	3 (9.6%)	1 (3.3%)	2 (6.7%)

An attempt was always made to graft all diseased vessels so as to allow complete revascularization. Grafting a diseases vessel was abandoned only if it was felt that the target vessel was too narrow to allow a satisfactory flow and patency rate. None of the cases required that grafting be abandoned due to intraoperative haemodynamic instability in the OPCAB group.

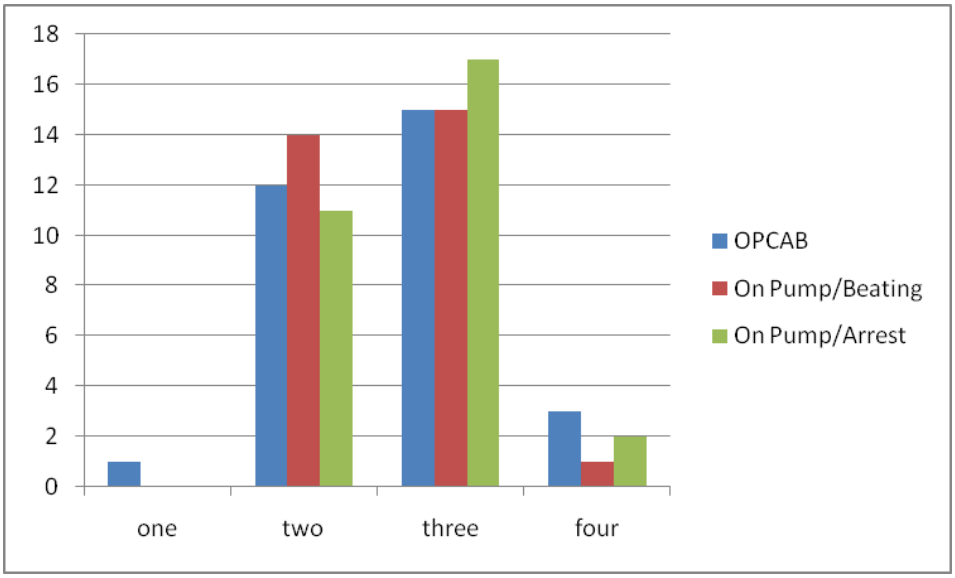

Figure 5:

Table 14: Type of conduit

Conduit	OPCAB	On Pump/Beating	On Pump/Arrest
LIMA	30	28	29
Radial artery	1	2	0
RSVG	51	52	52

A LIMA to LAD or D1 was routinely attempted in all cases. Cases with poor flow in LAD received RSVG. Three cases received a LIMA-radial Y-graft to D1

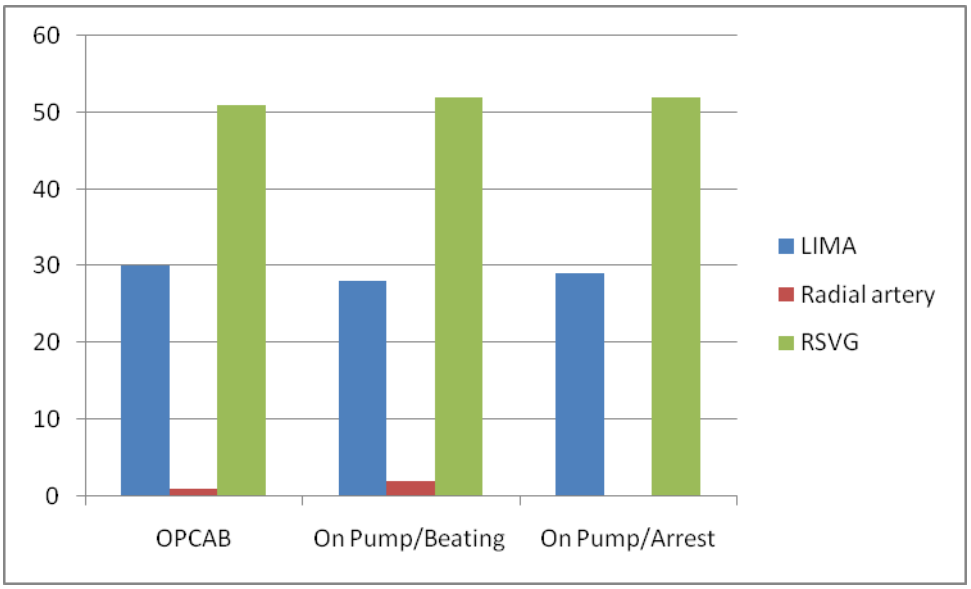

Figure 6:

Table 15: Duration of Surgery (hrs)

OPCAB	On Pump/Beating	On Pump/Arrest
4+0.5	4.4+0.6	4.5+0.3

No significant difference in operating time was found in the three groups.

Rate of Conversion to On Pump Beating Heart: A total of 4 cases required conversion to the on pump beating heart procedure due to intraoperative haemodynamic instability so that complete revascularization could be performed.These cases were therefore included in the On Pump Beating Heart Group.

Table 16: Post- Operative Details

Characteristics	OPCAB	On Pump/ Beating	On Pump/Arrest
Ventilation time(hrs)	9.4+1.4	9.5+2.4	9.8+1.4
No of units of blood transfused	5+2	8+2	8+2
Drainage (Post op bleeding)	434.166+239.1	652.6667+181.2	647.6667+236.7
Persistent Low Cardiac Output	2	7	2
Routine Ionotrope Usage: Intra op Post op	31 18	30 27	30 25
Potassium Abnormalities	1	3	3
Hb	9.2+1	8.5+1.2	8.2+1.2
Bilirubin	1.0+0.5	1.8+1.5	1.7+1.6
Post op MI (no of patients)	1	3	1
ICU Stay(Days)	2.3+.70	3.07+1.46	2.46+.93
Mediastinal Infection	1	1	0
Renal Dysfunction requiring dialysis	1	1	1
Re-exploration	1	2	2
Neurological Problems	1	1	1
Hospital stay (Days)	10+3	12+4	10+5
Mortality	2	5	3

Table 17

	P Value		
Parameter	Gr1:Gr2	Gr2:Gr3	Gr1:Gr3
Hb	.033	.86	.036
Drain	.035	.034	.67
Transf	.047	.08	.03
Ventilation	.943	.87	.95
Bil	.08	.09	.085
No of grafts	.943	.513	.847

Post op MI	.000	.000	.85
CNS Comp	1.00	1.00	1.00
Renal Comp	1.00	1.00	1.00
ICU stay	.000	.010	.08
Hospital stay	.000	.007	.005
Mortality	.015	.015	.06

No significant difference in was noted in the three groups as far as duration of ventilator support is concerned.

Transfusion requirements were significantly higher in the on pump groups. The on pump groups were associated with a higher post-operative drainage and had lower mean haemoglobin in the immediate post-operative period. Both on pump groups required significantly higher ionotrope usage during the post-operative period.

The on pump beating heart group had a significantly higher incidence of persistent low output state. The incidence of perioperative MI was also highest in the on pump beating heart group. No significant difference was found among the three groups with regard to incidence of neurologic, renal dysfunction or mediastinal infection. Duration of hospitalization and mortality were significantly higher in the on pump beating heart group

Discussion

Several large case series have demonstrated that beating-heart CABG surgery has a morbidity benefit, a cost benefit, a shorter period of hospitalization, and even a mortality advantage when compared to CPB-assisted CABG surgery. [10,12-14,21] Recent retrospective studies using more sophisticated statistical tools, such as case matching and propensity score analysis, have also suggested that beating-heart surgery is associated with decreased morbidity, as measured by decreased transfusion requirement, infection, length of hospitalization, renal failure, and encephalopathy, but not mortality.8,9 However, despite the use of advanced statistical methods meant to enable accurate comparisons, the inherent bias favoring fitter patients for beating-heart CABG may have gone unaddressed. Too far, four randomized controlled studies comparing CABG surgery with or without CPB have been conducted. The only significant differences in outcomes have been almost entirely in discretionary therapeutic end points (blood transfusion, time to extubation, time in ICU, and time in hospital), for which bias regarding on- or off-pump bypass assignment may have altered intervention or discharge thresholds. [15,16,18,22] The biggest reported trial (n=281) was a multicentre study that included only young individuals with normal ejection fraction and 1- or 2-vessel coronary artery disease. In beating-heart patients, the authors reported a quicker time to extubation (3 vs 9 hours) and a shorter stay of hospitalization (6 versus 7 days).

Intraoperative transfusion rates were decreased (3% against 13%) but not postoperatively (28% versus 29%). There were no additional changes in morbidity or death. Ascione et al [30] combined two 100-patient single-surgeon studies in low-risk patients with low rates of diabetes, peripheral vascular disease, and 3-vessel coronary artery disease. This group had lower blood transfusion rates (33% against 53%), shorter hospital stays (5 versus 7 days), and a lower incidence of atrial fibrillation (12% versus 37%) in beating-heart patients. Puskas et al. recently attempted to address these criticisms in a single-surgeon trial by randomizing 197 relatively unselected patients (no shock patients, no redo CABG, preoperative intra-aortic balloon pump) and reported shorter lengths of hospitalization (5 versus 6 days), shorter time to extubation, and lower transfusion rates (26% versus 44%). A recent meta-analysis of all randomized controlled trials found no significant difference between CABG done on the beating heart vs CPB. [23]

With 300 patients randomized, Legare et al's randomized controlled study comparing CABG operation done on the beating heart against CPB is the biggest to date. More than 30% of patients in this research were diabetic, and the majority had Canadian Cardiovascular Society angina class III/IV with severe lesions in all three coronary distributions. As a result, unlike the studies by Ascione et al [30,31] and Van Dijk et al [29], our patient sample may have been more reflective of contemporary CABG procedures, and unlike the studies by Puskas et al [22] and Ascione et al [30,31], we were not confined to a single-surgeon experience. Legare found an overall mortality rate of 1%, which did not vary substantially across groups and compares well to prior published research. A substantial majority of patients (66% in that series) had full arterial revascularization, with many having no proximal anastomoses into the aorta (54%). The mean or median number of grafts per patient was marginally lower for beating-heart patients (not statistically significant), although this might be due to a higher proportion of patients in the beating-heart group not having 3-vessel disease. Van Dijk et al. [29] had similar results.

Legare et colleagues revealed that in first-time isolated CABG, extremely low transfusion rates (9.3% vs 8.7%) may be obtained without special procedures, with no added advantage from beating-heart surgery. These results contrasted significantly from previous research, which found at least a transitory decrease in transfusion rates during beating-heart surgery. All of previous studies showed much higher transfusion rates than the current study, even in the beating-heart arm (28% vs 29% in van Dijk et al, [29] 33% versus 53% in Ascione et al,31 and 26% versus 44% in Puskas et al [22]). Despite the release of transfusion recommendations, it is clear that the discretionary end point of blood-product consumption following heart surgery varies greatly.

In contrast to earlier published studies, Legare et al were unable to establish any differences in time to extubation, duration of ICU stay, or length of hospitalization, suggesting that beating-heart surgery provides no benefit. The median time to extubation in both groups was 4 hours, the ICU stay was 22 hours, and the median duration of hospitalization was 5 days, all of which compare well to previously published studies. The findings imply that both surgical techniques may provide outstanding outcomes, and that the disparities seen in prior published trials may have been due to bias in discretionary end goals, despite attempts to standardize patient care. Because duration of hospitalization is one of the key variables influencing total cost, the current data imply that beating-heart surgery may have minimal financial benefit in the near run.

Perrault and colleagues [3] investigated an intermediary strategy between conventional and off-pump bypass. In their patients with poor ejection fraction, they employed on-pump beating heart (ONCAB/BH). They discovered that employing CPB without cross clamping and cardioplegic arrest while the heart is still beating results in reduced myocardial oedema and ischemia. According to their findings, such a strategy is helpful in reducing myocardial harm and may be utilized successfully in high-risk patients who cannot endure cardioplegic arrest or when using off-pump is not physically viable.

Since Perrault's breakthrough, other studies have been conducted employing the ONCAB/BH method for myocardial revascularization in both low and high risk patients. The approach was related with full revascularization and proven to be a dependable and successful treatment.

The major goal of employing the ONCAB/BH approach in high-risk patients is to prevent significant manipulation that might injure the myocardium and then conduct full revascularization. Surprisingly, Ahmad et colleagues discovered that the incidence of myocardial infarction was higher in individuals who received ONCAB/BH vs OPCAB, indicating that manipulation of the heart, even when supported by the bypass machine, is still hazardous.

Rastan and colleagues [4] discovered an increased risk of myocardial damage while utilizing ONCAB/BH in individuals with normal ejection fraction when compared to off-pump. Despite the fact that the result had little clinical relevance, they thought that such a strategy is not favorable to off-pump bypass. Pegg and colleagues [11] validated these results, revealing that the frequency of new irreversible myocardial damage in patients with compromised LVF was considerably greater in ONCAB/BH patients than in traditional bypass patients.

In our investigation, there was no significant difference in the number of grafts obtained across the three groups. There was no variation in the duration of ventilator support post-operatively. The on-pump group required considerably more transfusions. The on pump groups showed greater post-operative drainage and lower mean hemoglobin levels in the immediate post-operative time.During the post-operative period, the on pump groups needed considerably more ionotropes. The group with an on-pump pumping heart had a considerably greater prevalence of prolonged low output status.

Perioperative MI was also more common in the on-pump beating heart group. There was no significant difference in the incidence of neurologic, renal impairment, or mediastinal infection across the three groups. The on-pump beating heart group had a considerably longer hospital stay and a higher death rate. The higher incidence of perioperative MI and death in the on pump beating heart group might be explained by undetected ischemia during cardiac manipulation while haemodynamic parameters remained constant owing to pump assistance. This covert ischemia may have increased the incidence of post-operative prolonged low output status and MI.

In theory, however, on pump beating heart surgery may benefit a subset of patients with very low LVEF because cardioplegic techniques may result in further myocardial stunning and OPCAB may result in under grafting due to intraop haemodynamic instability.

Conclusion

Both OPCAB and on-pump CABG with cardioplegic arrest have great short-term outcomes in terms of mortality/morbidity. There was no significant difference in the number of grafts obtained between the three groups. The

on-pump group required considerably more transfusions. The on pump groups showed greater post-operative drainage and lower mean hemoglobin levels in the immediate post-operative time. During the post-operative period, the on pump groups needed considerably more ionotropes. The group with the on-pump beating heart had a considerably greater prevalence of chronic low output status. Perioperative MI was also more common in the on-pump beating heart group. There was no significant difference in the incidence of neurologic, renal impairment, or mediastinal infection across the three groups.

The on pump beating heart group had a much longer hospital stay and a greater death rate. Because it is linked with a little greater mortality and morbidity, on pump beating heart CABG should not be regarded a compromise between OPCAB and traditional on pump procedures. More research is needed to identify specific subgroups of patients (such as those with extremely low LVEF) who may benefit from this method.

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