Original Article

Off-pump On-pump Coronary Artery Bypass Decision-making

Raafat I. Shalabi, MD

Background: Coronary revascularization on the beating heart is an attractive to option conventional coronary artery bypass graft (CABG) but remains controversial. Our study encourages sufficient proper time for decision-making when changing CABG from off-pump to on-pump CABG. We report herein patients who changed from off-pump CABG to on-pump CABG.

Methods: A retrospective analysis of 240 patients operated upon at Cardiology Hospital of Lyon University between July 1998 and July 2000, and at one unit of Cardiac Surgery, yielded 88 patients with off-pump coronary surgery (off CAB), 21 patients changed from off-pump CABG to on-pump CABG. The other 131 patients were operated on as on-pump CABG.

Results: There was no operative mortality. One month postoperative mortality was only one patient out of 21 due to cardiac failure and arrhythmias. There was no significant difference in the postoperative intensive care unit (ICU) time and length of hospital stay compared with off-pump CABG.

Conclusion: Our data suggest that a fair number of patients are potential candidates for off CAB. The only contraindication is the technical limitation or the surgeon comfort level. Changing from off CAB to on CAB can be decided for the patient's safety within the appropriate time intraoperatively without fear of more postoperative complications than with off CAB surgery. (Ann Thorac Cardiovasc Surg 2002; 8: 135–8)

Key words: coronary artery bypass, off-pump, on-pump

Introduction

Conventional coronary artery bypass grafts (CABG) have been performed with reproducible success, but complications cause significant morbidity.[1)] Since these complications are multifactorial, avoidance of cardiopulmonary bypass (CPB) may not translate into clinical benefits.

Nevertheless, advocates of off CAB have proposed that theoretical advantages of avoiding CPB are a decreased incidence of neurological dysfunction, postoperative myocardial infarction (MI), bleeding, renal failure and respiratory failure.[1-5)]

Nobody can deny that CABG is one of the most important developments in cardiac surgery and has made it possible for surgeons to perform coronary revascularization on a still and bloodless heart. However, stopping the heart and temporarily replacing its functions with the heart-lung machine has risks associated with it.[6,7)] Patients realize substantial benefits from undergoing beating heart CABG.[8-12)]

As the importance of the benefits of off CAB was documented by others, documenting the postoperative outcome for those patients who changed from off-pump CABG to on-pump CABG was our aim. Comparing these outcomes along with the examination of recovery times and resource utilization will hopefully provide an accurate answer for changing the patient from off-pump to on-pump CABG as a safe decision intraoperatively.

From the Department of Cardiovascular Surgery, Cardiology Hospital, Lyon, France, and the Department of Vascular Surgery, King Fahad Hospital, Madinah Al Munawarah, Kingdom of Saudi Arabia

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Address reprint requests to Raafat I. Shalabi, MD: Consultant Cardiovascular and Thoracic Surgery, Head, Department of Vascular Surgery, King Fahad Hospital, Madinah Al Munawarh, Kingdom of Saudi Arabia.

Materials and Methods

At our unit, off CAB surgical techniques were instituted in the mid-half of 1998. A total of 240 patients underwent CABG from July 1998 until July 2000. Eighty-eight patients had off-pump coronary surgery, 21 patients were intraoperatively operated upon with on-pump CABG after being off-pump CABG, and 131 patients were operated on from the start as on-pump CABG. We compared the postoperative course of patients with off-pump CABG to those patients who were changed from off-pump to on-pump CABG intraoperatively.

Surgical Techniques

Off-pump CABG

After induction of anesthesia, the internal mammary arteries (mainly left LIMA and mostly right IMA) were harvested along with the other conduits of saphenous vein. After heparinization and the active clotting time (ACT) was maintained >300 seconds. Depending on the target, exposure was carried out using a variety of techniques. The left anterior descending (LAD) artery and the diagonal branches were exposed by placing a deep pericardial suture to elevate and rotate the targets into the surgeon's view. For exposure of the lateral vessels the obtuse marginal and the posterolateral branches of the circumflex, we employed pericardial traction sutures at the left superior and inferior pulmonary veins, the posterior descending artery (PDA) being exposed with placement of a suture near the inferior vena cava. Our technique of exposure was followed by the one stitch technique deeply at the oblique sinus of the pericardium. Both techniques of traction sutures, along with placing the patient in the Trendelenberg position, opening the right pleura and incising the right pericardium exposed the lateral coronary arteries adequately without significant hemodynamic compromise. Stabilization was carried out with the help of a mechanical stabilizer. For patients with deseased intramyocardial coronary vessels, or in need for endarterectomy or small vessel diameter (<1.25 mm) the use of conventional CABG was decided. Standard CPB with mild to moderate systemic hypothermia was used with cold cryataloid antegrade cardioplegia to arrest the heart, and anatomosis was continued on a stationary heart. Partial aortic clamping was used for the proximal anatomosis. Distal anastomosis in both groups were performed prior to proximal anastomosis in all patients, with the LIMA and LAD anastomosis performed first.

All patients were transported to the intensive care unit (ICU) postoperatively and patients were extubated as per standard procedures (with documentation of adequate levels of awakening, ability to oxygenate and lack of hypercarpia). Chest drains were removed when drainage was less than 100 ml over 24-hour period. All patients were subjected to the same postoperative recovery protocols both in the ICU and on the wards, including criteria for transfusion of blood products.

Data was collected and examined retrospectively in all patients, focusing on preoperative characteristics as well as the postoperative outcomes such as time on mechanical ventilation, ICU and overall postoperative length of stay (LOS), number of blood transfusions, incidence of metabolic acidosis (as defined by HCO_3<21 mml) and peak levels of creatinine phosphokinase (CPK) in the first 24 hours. The occurrence of atrial fibrillation, reoperation for bleeding, stroke, perioperative myocardial infarction and mortality were recorded. Fixed and variable costs for each patient were obtained and were evaluated for their association to age and STS risk scores within each group. Continuous data was analyzed using a paired *t test*, while categorical values were analyzed using a Mc Nemer chi square test. Both tests took into account that patients were matched prior to statistical analysis, with significance indicated by *P values* less than 0.05. Cost difference between the two groups, as well as relationship between age and cost, and preoperative risk score and cost were examined using a *t test*.

Results

In both groups of off-pump CABG and off-pump to on-pump CABG, 85 were males and 24 were females. There were 15 males and 6 females in the 21 patients who were intraoperatively operated upon with on-pump CABG after being off-pump CABG. Both groups were similar in preoperative clinical characteristics. They did however differ in the average number of distal anastomosis performed (off CAB, 2.5; off-pump to on-pump CAB, 2.8; P=0.001), which appeared to be related to the presence of two of three vessel coronary artery disease which was insignificant between the two groups P<0.005.

Incidence and causes of changing from off-pump to on-pump CABG were summarized in Table 1. Incision to dressing operating room time was on the average 40 minutes shorter with off-pump CAB operations. Average time on the ventilator was not significantly lower for the off CAB group than off- to on-pump CAB group (Table 2) with 76.6% of off CAB patients extubated within 6

Table 1. Incidence and causes to change off to on-pump CABG

Causes	Number	%
1. Low cardiac output	10	47.6
2. Endarterectomy	3	14.3
3. Intramyocardial coronary vessel	4	19.0
4. Small tapered coronary vessel	3	14.3
5. Sudden arrhythmias	1	4.8
Total	21	100

hours of ventilation in comparison to 60% of the off- to on-pump group. There was no significant difference in both the mean ICU stay and the overall postoperative length of stay. The mean postoperative length of stay for the off CAB group was 8 days, and for the off- to on-pump group was 8.5 days. The average number of packed red blood cell transfusions and platelets were not significantly different in both groups on the first postoperative days (Table 2). No significant differences were found in the incidence of atrial fibrillation (off CAB, 19.38%; off- to on-pump CABG, 23.8%; P=0.845), stroke, perioperative myocardial infarction, reoperation for bleeding, or mortality (one patient died in off- to on-pump group (4.76%)). Mean variable costs were found to differ significantly in the off CAB group.

Discussion

By eliminating the need for cardiopulmonary bypass, off-pump surgery has theoretical clinical advantages over conventional on-pump procedures, in the past due to the absence of the marked systemic inflammatory response elicited by extracorporeal circulation during on-pump procedures.[13,14] This phenomenon may theoretically lead to a reduction in specific organ system dysfunction related to cardiopulmonary bypass especially in high-risk populations (e.g., those with chronic obstructive pulmonary disease and renal dysfunction). Limiting the physiologic trauma of the operation would thus promote faster recovery, particularly in susceptible populations with a relatively greater number of co-morbidities, such as the elderly.

A major concern is the clinical outcomes not addressed in this report centered around long-term patency with this technically more difficult procedure. Although some reports have documented excellent early patency with off-pump CAB techniques,[15-19] Arom et al. recently reported higher rates of reoperation for graft occlusion in off-pump CAB patients as well as more frequent subsequent readmissions for angina and reintervention.[20] Accurate follow-up over time is thus essential and will provide answers to these concerns.

In the beginning of our experience, off-pump CAB was reserved mainly for patients with multiple risk factors that would make an operation on CBP hazardous. These include older patients (>75 years), patients with cerebrovascular, renal or respiratory problems and patients with an extremely atherosclerotic aorta. Other candidates include patients with immunosuppresion or those who have a malignancy. Revascularization of the most important target vessel or vessels (Culprit lesions) should be the aim. With a patient with minimal or no risk factors for CABG operations, incomplete revascularization is unacceptable. No vessel planned preoperatiavely to be bypassed should be skipped. There should be no hesitation to convert the operation from off-pump to on-pump CAB, if complete revascularization cannot be accomplished with off CAB, since this represents a major benefit for the patient. It has been shown that elective conversion of an off CAB operation does not increase morbidity, while urgent conversion due to severe hemodynamic instability can be hazardous,[19] or due to sudden ventricular arrhythmia.

We found no significant differences in rates of major complications which would account for significant cost differences. The relatively small number of patients examined limits our study. By case-matching patients for preoperative characteristics that would have impact on length of stay, our data suggest that with the use of off CAB surgery, the shorter average operating room time noted, is likely due to the time required for cannulation

Table 2. Postoperative follow-up

Mean	Off-pump CAB	Off-pump on-pump CAB
1. Ventilation time (hours)	6.2	6.9
2. ICU (days)	1	1.5
3. Postoperative length of stay (days)	8	8.5
4. Blood transfusion and products	0.5	0.5
5. % atrial fibrillation	19.38 (17 patients)	23.8 (5 patients)

and achieving proper and complete vascularization, in addition to rewarming the patient and achieving homeostasis than with off-pump CAB.

There were no significant differences in postoperative complications regarding MI, new onset atrial fibrillation, and neurologic dysfunction (3.7% vs. 6.7%). There were two strokes in the off CAB group and one in the off-pump to on-pump CAB group. No significant differences with respect to renal failure; respiratory failure and deep sternal wound infection. Cost saving of patients with off CAB surgery have also been documented, with reductions in costs ranging from 14 to 30%.[16,18,21] Our cost was mainly from utilizing the on-pump techniques but by using disposable stabilizers has decreased the use of limited and costly resources without compromising safety for those who undergo this operation.

In summary, the surgeon's decision-making remains the most important factor contributing to the outcome of the operation. A good indication, solid judgment, perfect anastomosis, complete revascularization, knowing where to stop or convert, patience and experience remain the important assets for a good result.

References

1. Reed G, Singer D, Picard E, et al. Stroke following coronary artery bypass surgery. A case-control estimate of the risk from carotid bruits. *N Engl J Med* 1988; **319**: 1246–50.
2. Savageau JA, Stanton BA, Jenkins CD, et al. Neuropsychological dysfunction following elective cardiac operation. 1. Early assessment. *J Thorac Cardiovasc Surg* 1982; **84**: 585–94.
3. Shaw PJ, Bates D, Cartlidge NE, et al. Neurologic and neuropsychological morbidity following major surgery: comparison of coronary artery bypass and peripheral vascular surgery. *Stroke* 1987; **18**: 700–7.
4. Bouchard D, Cartier R. Off-pump revascularization of multi-vessel disease has a decreased myocardial infarction rate. *Eur J Cardiothorac Surg* 1998; **14** Suppl 1: S20–4.
5. Ascione R, Lloyd CT, Gomes WJ, et al. Beating vs arrested heart revascularization: evaluation of myocardial function in a prospective randomized study. *Eur J Cardiothorac Surg* 1999; **15**: 685–90.
6. Elefteriades JA. Mini-CABG: a step forward or backward? The "pro" point of view. *J Cardiothorac Vasc Anesth* 1997; **11**: 661–8.
7. Gu YJ, Mariana MA, Van Oeveren W, et al. Reduction of the inflammatory response in patients undergoing minimally invasive coronary artery bypass grafting. *Ann Thorac Surg* 1998; **65**: 420–4.
8. Buffolo E, Andrade JCS, Succi JE, et al. Direct myocardial revascularization without extracorporeal circulation: technique and initial results. *Tex Heart Inst J* 1985; **12**: 33–41.
9. Borst C, Jansen EWL, Tulleken CAF, et al. Coronary artery bypass grafting without cardiopulmonary bypass and without interruption of native coronary flow using a novel anastomosis site restraining device ("Octopus"). *J Am Coll Cardiol* 1996; **27**: 1356–64.
10. Buffolo E, Gerola LR. Coronary bypass grafting without cardiopulmonary bypass through sternotomy and minimally invasive procedure. *Int J Cardiol* 1997; S89–93.
11. Burfeind WR, Duhaylongsod FG, Samuelson D, et al. The effects of mechanical cardiac stabilization on left ventricular performance. *Eur J Cardiothorac Surg* 1998; **14**: 285–9.
12. Calafiore AM, Giammarco GD, Teodori G, et al. Recent advances in multivessel coronary grafting without cardiopulmonary bypass. *Heart Surg Forum* 1998; **1**: 20–5.
13. Wan S, Izzat MB, Lee TW, Wan T, Tang N, Yim A. Avoiding cardiopulmonary bypass in multivessel CABG reduces cytokine response and myocardial injury. *Ann Thrac Surg* 1999: **68**: 52–7.
14. Matata BM, Sosnowski AW, Galinanes M. Off-pump bypass graft operation significantly reduces oxidative stress and inflammation. *Ann Thorac Surg* 2001; **69**: 785–91.
15. Calafiore AM, Di Giammarco G, Teodori G, Mazzei V, Vitolla G. Recent advances in multivessel coronary grafting without cardiopulmonary bypass. *Heart Surg Forum* 1998; **1**: 20–5.
16. Puskas JD, Wright CE, Ronson RS, Brown WM, Gott JP, Guyton RA. Off-pump multivessel coronary bypass via sternotomy is safe and effective. *Ann Thorac Surg* 1998; **66**: 1068–72.
17. Cartier R. Systemic off-pump coronary revascularization: experience of 275 cases. *Ann Thorac Surg* 1998; **68**: 1494–7.
18. Boyd WD, Desai ND, Del Rizzo DF, Novick RJ, McKenzie FN, Menkis AH. Off-pump surgery decreases postoperative complications and resource utilization in the elderly. *Ann Thorac Surg* 1999; **68**: 1490–3.
19. Stanbridge R. An overview of beating heart surgery. In: Trends in Cardiac Surgery. Academic Pharmaceutical Productions BV, 1998.
20. Arom KV, Flavin TF, Kshettry VR, Janey PA, Petersen RJ. Safety and efficacy of off-pump coronary artery bypass grafting. *Ann Thorac Surg* 2000; **69**: 704–10.
21. Arom KV, Emery RW, Flavin TF, Petersen RJ. Cost-effectiveness of minimally invasive coronary artery bypass surgery. *Ann Thorac Surg* 1999; **68**: 1562–6.