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Off-Pump Coronary Artery Bypass Grafting in a Low-Volume Center

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ABSTRACT

Background: The advantages of off-pump coronary artery bypass grafting (OPCAB) are well documented; however, the conversion of OPCAB to cardiopulmonary bypass (CPB) is associated with higher morbidity and mortality. This issue is of particular concern in low-volume centers or centers that are beginning to use OPCAB. We present an OPCAB methodology that uses a maximum number of arterial grafts.

Methods: We routinely use OPCAB in every patient unless there is another associated condition. We used the following methods to improve the safety of OPCAB: (1) maintaining normothermia, (2) routine use of a pulmonary artery catheter, (3) routine use of a femoral arterial line, (4) routine use of a cell saver, and (5) complete revascularization.

Results: We included 173 consecutive patients in the study. All patients underwent OPCAB without any conversion to CPB. Hemodynamic compromise in 5 patients (2.89%) required insertion of an intra-aortic balloon pump (IABP). OPCAB was completed in all 5 patients after IABP insertion. Blood transfusions (BTs) were avoided in 55 patients (31.8%), and 68 patients (39.3%) required ≤2 units of blood.

Conclusion: The OPCAB technique is still evolving. Low-volume centers have higher rates of conversion to CPB. Hypotension due to an impaired left ventricular function can be successfully treated by using an IABP. Although blood loss can be managed with BTs, use of a cell saver helps to reduce the number of BTs. We conclude that our technique of total arterial OPCAB using a cell saver can be safely performed in a low-volume center.

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INTRODUCTION

The advantages of off-pump coronary artery bypass grafting (OPCAB) are well documented [Puskas 2004; Bainbridge 2005; Parolari 2005; Wijeysundera 2005; Al-Ruzzeh 2006]. Moreover, internal thoracic artery (ITA) grafts have proved to have the best long-term patency rates [Pick 1997; Calafiore 2000; Tector 2001]. Therefore, it is logical to combine the 2 techniques to maximize the benefits [Raja 2009]. Totally arterial OPCAB has not found universal acceptance, however, particularly in low-volume centers or among younger surgeons. A study has documented a higher rate of complications in low-volume centers, with higher morbidity but with no significant increase in mortality [Brown 2001]. Despite the well-documented benefits of OPCAB without conversion to cardiopulmonary bypass (CPB), mostly from high-volume centers, no protocol for preventing such a conversion has been documented in the literature. We present an OPCAB methodology that uses a maximum number of arterial grafts.

MATERIALS AND METHODS

We routinely use OPCAB in every patient unless there is another associated condition. We use the following methods to improve OPCAB safety:

1. Normothermia is maintained with the following measures:
    - The operating room temperature is maintained at 22°C to 23°C and lowered only after the patient has been fully draped.
    - A warming blanket is placed on the operating table with water circulating at 41°C.
    - A hot-air warmer is placed between the legs of the patient to prewarm the patient; the patient is kept covered during line insertion and anesthesia induction. An additional warmer may be used near the head end of the patient during OPCAB.
    - All intravenous fluids are warmed with an online fluid warmer.
2. A pulmonary artery (PA) catheter is used routinely, with the PA pressure monitored in every patient. Moreover, inotrope lines are kept connected to the

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patient so that they can be started immediately if any need arises.

3. A femoral arterial line is used routinely in every OPCAB patient. The line can be used for insertion of an intra-aortic balloon pump (IABP), if required. IABP electrocardiographic leads are attached to the back of the patient simultaneously with the attachment of monitoring electrocardiographic leads before induction.
4. A cell saver is used from the beginning of the operation.
5. Complete revascularization is performed in every patient.

Surgical Technique

All operations were performed through a median sternotomy. ITAs were harvested extrapleurally in a skeletonized or semiskeletonized fashion. The radial artery was harvested with a thin pedicle. OPCAB is performed by using a suction-type cardiac stabilizer (Octopus 4.3; Medtronic, Minneapolis, MN, USA). We do not use a cardiac-positioning device, but we do use warm swabs behind the heart to facilitate optimal positioning for grafting. Intracoronary shunts were used almost routinely; we use a shunt that is 1 size smaller (eg, a 1.25-mm shunt for a vessel that will accept a 1.5-mm shunt). The only exception to the routine use of a shunt is a small vessel size (<1.25 mm) and a vessel other than the left anterior descending artery (LAD). For a vessel in which a shunt is not used, we use proximal occlusion, and we do insert a smaller-sized shunt distally while suturing near the toe of the anastomosis. Any vessel >1 mm with a significant stenosis is grafted. In the presence of diffuse coronary artery disease or left ventricular (LV) dysfunction, we perform complete revascularization aggressively, even if we have to perform 6 or 7 grafts.

Grafting Strategy

Our routine practice is never to lift the heart or try to see the target vessel other than the LAD after pericardiotomy. The LAD is easily visible after pericardiotomy. It can be gently palpated in the case of diffuse LAD disease to determine the optimum site of grafting. After harvesting the grafts, we first graft the LAD with one ITA. We routinely use an intracoronary shunt for LAD grafting. After successful ITA-to-LAD grafting, we explore and look at the targets and decide how to use the other ITA and the radial artery.

If hemodynamic compromise refractory to inotropic therapy occurs at any point during the procedure, we insert an IABP via the femoral access. The only situation in which we found that IABP insertion might not produce a remarkable improvement in hemodynamics was when there was acute occlusion of a critically stenosed right coronary artery (RCA) that had yet to be revascularized. This situation may be precipitated during LAD grafting. In this situation, we use a saphenous vein graft from the aorta to the posterior descending artery. This procedure has produced an improvement in hemodynamics.

RESULTS

In this study, we included 173 consecutive patients who underwent their operations by a single surgeon (K.K.S.). All 173 patients underwent OPCAB without any conversion to CPB. Hemodynamic compromise in 5 patients (2.89%) required the insertion of an IABP; OPCAB was completed in all 5 patients after IABP insertion. Table 1 shows the distribution of the patients according to the LV ejection fraction (LVEF). Table 2 shows the distribution of the patients according to the number of grafts performed. Approximately one-third (34.7%) of the patients received 4 grafts. The maximum number of grafts performed in a single patient was 8 grafts; the minimum was 2 grafts. Both ITAs were used in 160 patients (92.5%). The mean number of grafts per patient was 4.18. The mean number of arterial grafts per patient was 3.75, and the mean number of venous grafts per patient was 0.43. Table 3 and the Figure show the distribution of arterial and venous grafts in patients with different LVEFs. Table 4 shows the distribution of patients according to their arterial and venous grafts. Blood transfusion (BT) was avoided in 55 patients (31.8%), and 68 patients (39.3%) required ≤2 units of blood (Table 5).

DISCUSSION

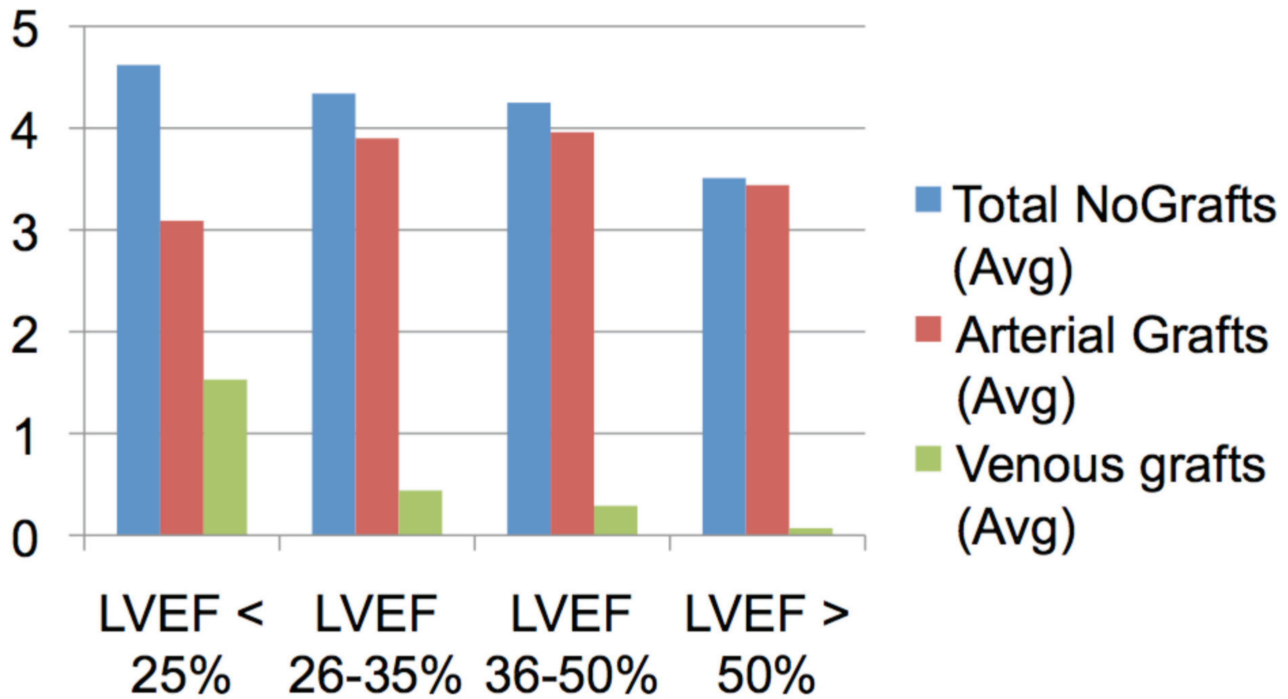
The OPCAB technique is still evolving. Low-volume centers have higher rates of conversion to CPB [Edgerton 2003; Hovakimyan 2008]. Conversion of OPCAB to CPB is associated with higher morbidity and mortality [Soltoski 1998; Edgerton 2003; Patel 2004; Hovakimyan 2008; Mukherjee 2011]. That fact may be a reason why OPCAB has found limited popularity, particularly in low-volume centers or among younger surgeons.

Table 1. Left Ventricular Ejection Fractions (LVEFs) of the Patients Undergoing Off-Pump Coronary Artery Bypass Grafting

LVEF	Patients, n	Mean LVEF
<25%	21 (12.1%)	21.4%
26%-35%	61 (35.3%)	33.9%
36%-50%	52 (30%)	41.8%
>50%	39 (22.6%)	51.3%

Table 2. Distribution of Patients by the Number of Grafts

No. of Grafts	Patients, n
2	15 (8.7%)
3	35 (20.2%)
4	60 (34.7%)
5	38 (21.9%)
6	18 (10.4%)
7	6 (3.5%)
8	1 (0.6%)



Distribution of arterial and venous grafts in the patients according to the left ventricular ejection fraction (LVEF).

Table 3. Distribution of Arterial and Venous Grafts in Patient Groups with Different Left Ventricular Ejection Fractions (LVEFs)

LVEF	Patients, n	Mean Grafts/Patient, n	Mean Arterial Grafts/Patient, n	Mean Venous Grafts/Patient, n
<25%	21 (12.1%)	4.62	3.09	1.53
26%-35%	61 (35.3%)	4.34	3.90	0.44
36%-50%	52 (30%)	4.25	3.96	0.29
>50%	39 (22.6%)	3.51	3.44	0.077
Total	173	4.18	3.75	0.43

OPCAB Conversion

Hemodynamic compromise is the most common cause of OPCAB conversion to CPB [Mukherjee 2011]. That can happen because of a decrease in preload due to continued blood loss or LV dysfunction caused by myocardial ischemia. An operating surgeon's inexperience with OPCAB is well documented to be associated with a higher rate of conversion to CPB [Edgerton 2003; Hovakimyan 2008]. In addition, the rate of OPCAB conversion to CPB in a particular center has been observed to decrease over the years as experience with the procedure increases in that center. One can argue that many of these conversions can be attributed to a panic reaction by a relatively inexperienced OPCAB surgeon. Moreover, no standardized protocol from the high-volume OPCAB centers with low conversion rates has been published in the literature.

IABP during OPCAB

IABPs have been successfully used in cardiogenic shock and to wean coronary artery bypass grafting patients from CPB. It is logical to argue that intraoperative hypotension occurring during OPCAB may be due to myocardial ischemia and that it can be managed by inserting an IABP. We have seen that hypotension due to an impaired LV function can be successfully treated with an IABP. Five (2.89%) of our patients required insertion of an IABP during OPCAB. It is our practice to insert an IABP in cases of hemodynamic compromise refractory to inotropic therapy. A report has described using a percutaneous ventricular-assist device during OPCAB [Gregoric 2008]; however, the use of an IABP during OPCAB to prevent conversion to CPB has not been reported in the literature. In our experience, IABP support works extremely well during OPCAB if the hemodynamic compromise is due to myocardial ischemia. The reason for a lack of improvement in a patient's hemodynamics after IABP insertion may be acute occlusion of a critically stenosed RCA that has yet to be revascularized. This situation may be precipitated during LAD grafting. In this situation, we use a saphenous vein graft from the aorta to the posterior descending artery. This procedure has produced an improvement in hemodynamics.

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Table 4. Distribution of Patients with regard to Arterial and Venous Grafts

Graft Type	Patients, n
All-arterial grafts	132 (76.3%)
Vein grafts, n	
1	17 (9.8%)
2	16 (9.2%)
3	6 (3.5%)
4	2 (1.2%)

Table 5. Blood transfusions and Hemoglobin (Hb) Concentrations of Patients before and after Surgery*

		Mean Hb Concentration, g/dL		
Transfusions, n	Patients, n	Preoperative	Postoperative	Predischarge
0	55 (31.8%)	13.6	12.6	11.1
≤2	68 (39.3%)	13.3	12.5	11.8
>2	50 (28.9%)	11.7	15.6	11.8

*Preoperative indicates mean Hb concentration in the group before OPCAB; postoperative, mean Hb concentration in the group immediately after shifting from the operating room; predischarge, mean HB concentration in the group immediately before discharge from the hospital.

Routine Cell Saver Use during OPCAB

The impact of routine use of a cell saver during OPCAB was remarkable—31.8% of the patients required no BT, and another 39.3% received 1 or 2 units of blood. More than 2 units of blood were used in fewer than one-third of the patients, and most of these patients had multiple risk factors.

Another problem during OPCAB is ongoing blood loss from the operating field. Although blood loss can be managed by BT, use of a cell saver helps to reduce the number of BTs. If there is ongoing blood loss during OPCAB and the surgeon in a low-volume center is relatively inexperienced, it cannot be denied that the presence of a cell saver will increase the surgeon's confidence and comfort to successfully complete the OPCAB procedure.

Moreover, in cases of ongoing blood loss during OPCAB grafting, the use of a cell saver allows the surgeon to remain stress free to complete the grafting with perfection. In addition, our use of an intracoronary shunt that is 1 size smaller not only makes distal grafting less technically demanding but also decreases endothelial injury. Our impression is that routine use of a cell saver allows us the luxury of using a smaller intracoronary shunt. The blood lost caused by the use of a smaller-sized intracoronary shunt can be easily transfused back into the patient.

OPCAB and Complete Revascularization

In our series, 71.1% of the patients received 4 or more grafts, which is comparable to any on-pump coronary artery bypass grafting series. Our patients also received a mean of 4.18 grafts per patient. We feel that because we have a cell saver as a backup for ongoing blood loss and any stress regarding an increasing pump time or clamp time is absent, complete revascularization is performed more often than not. As Table 2 illustrates, we were able to perform 6, 7, or even 8 grafts successfully with our OPCAB protocol.

Safety of Arterial Grafts

Studies published as early as 1997 have proved that bilateral ITAs grafted in situ to the left coronary system can produce a statistically significant survival advantage after 10 years of follow-up [Pick 1997]. Subsequently, the superiority of bilateral ITA grafting has been well documented by many authors [Calafiore 2000; Tector 2001; Raja 2009]. There is a concern, however, of having one inflow in cases of a left ITA–right ITA T or Y graft. In our series, we have used one ITA to graft the LAD. The other ITA was used to create a composite graft with the radial artery. Totally arterial OPCAB using a dual inflow has been reported by 2 groups [Fuster 2002; Tanaka 2008]. In our technique, we graft the LAD with the left ITA (most commonly) or with the right ITA; we then construct the composite graft. We believe that this period of LAD revascularization, when the composite graft is created, possibly helps in the partial recovery of ischemic ventricular dysfunction. That may explain our success with OPCAB without conversion.

Moreover, we have a very low threshold for using vein grafts. Although both ITAs were used in 92.5% of the patients, totally arterial revascularization was possible in only 76.3% of the patients. When things are not going well in the operating room during OPCAB, prompt identification of the offending artery (most often a critically narrowed RCA) and using a vein graft to revascularize this artery will often turn things around. Use of a vein graft in a planned totally arterial OPCAB should not be considered a failure. As we can see from Table 3, the patients with ventricular dysfunction often received venous grafts, whereas patients with a normal LVEF received fewer total grafts and mostly arterial grafts.

Conclusion

The lack of conversion to CPB in more than 173 consecutive unselected patients is proof of the remarkable safety of our OPCAB protocol. Arterial grafts can be safely used in a low-volume center with good clinical judgment. Routine use of a cell saver during OPCAB reduces BT requirements and increases operator confidence and comfort. The impact of routine use of a cell saver on the OPCAB conversion rate needs to be studied. The use of an IABP to treat hemodynamic compromise during OPCAB has not been studied with a large number of patients. This issue requires future investigation. We conclude that our technique of OPCAB using arterial grafts can be safely performed in a low-volume center.

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