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# Routine Intracoronary Shunting in Multivessel Off-Pump Coronary Artery Bypass: A Retrospective Review of in-Hospital Outcomes in 550 Consecutive Cases

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## ABSTRACT

**Background:** Since 1999 our institution has adopted off-pump coronary artery bypass grafting (OPCABG) for treating the majority of our patients. In the year 2001, 96% of our isolated coronary bypass procedures were performed on the beating heart. Routine use of intracoronary shunts in OPCABG has been a controversial topic. We use routine intracoronary shunting in all cases to maintain distal perfusion and to help achieve hemostasis.

**Methods:** We reviewed the first 550 OPCABG procedures performed at our institution (July 1998-December 2001) by 2 surgeons currently performing >95% of all coronary bypasses off-pump. All cases were completed with routine intracoronary shunting using Flo-Coil (Guidant, Santa Clara, CA, USA) or Flo-Thru (Bio-Vascular, St Paul, MN, USA) shunts. The mean number of grafts was 3.7. (range, 1-8). In-hospital outcomes in this series of patients were compared to outcomes in 485 patients operated on by the same 2 surgeons using traditional cardiopulmonary bypass (CPB) and aortic cross-clamping prior to adopting routine OPCABG. Statistical significance was calculated using Pearson chi-square analysis and reported for *P* values of <.05.

**Results:** The rates of occurrence of postoperative cardiovascular accident, atrial fibrillation, prolonged ventilator time, renal failure, and blood product use and the length of postoperative stay were significantly less in the off-pump group ($P < .05$). Predicted risk of mortality, observed mortality, and perioperative myocardial infarction rates were not significantly different in the 2 groups ($P < .05$). The conversion rate was 3.1%.

**Conclusion:** We conclude that routine intracoronary shunting in OPCABG is a safe technique that is associated with good myocardial preservation and allows for total revascularization with a low rate of conversion to CPB.

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## INTRODUCTION

Off-pump coronary artery bypass grafting (OPCABG) has quickly become a well-established technique for coronary revascularization. Numerous studies (most of which have been retrospective reviews) have shown reduced morbidity when cardiopulmonary bypass (CPB) is avoided in isolated coronary revascularization [Stamou 2001, Angelini 2002, Magee 2002].

The routine use of intracoronary shunts during OPCABG is not a common practice among beating-heart surgeons. Intraluminal shunts have thus far not been shown to improve myocardial preservation during OPCABG in the clinical setting, and their possible role in endothelial injury continues to be of concern.

We adopted OPCABG in 1999 for all isolated coronary revascularizations and have been using intraluminal coronary shunting routinely in all cases. We feel that shunting facilitates a more accurate, less hurried anastomosis and contributes to hemodynamic stability in multivessel coronary grafting. We have not observed any clinical ill effects of possible endothelial injury in our patient population.

We believe that this approach has allowed us to offer off-pump coronary bypass to all comers, including high-risk patients (eg, patients with acute myocardial infarction [MI], poor left ventricular [LV] function, and reoperations) and to achieve total revascularization with a fairly low rate of conversion to CPB.

This review reports our examination of the first 550 patients at a single institution who underwent surgery using this approach and comparison of their outcomes to those of a cohort of patients with similar demographics who underwent CPB surgery prior to the adoption of routine OPCABG.

## MATERIAL AND METHODS

Our institution's Society of Thoracic Surgery (STS) database was interrogated to review demographics and in-hospital clinical outcomes in 1035 isolated coronary artery bypass procedures performed by 2 surgeons (HHB and CCQ) since 1997. The on-pump cohort (CPBCABG) consisted of 485 consecutive patients who underwent surgery during

Table 1. Preoperative Characteristics for On- and Off-Pump Cohorts*

| Demographics | Off Pump | On Pump | *P* |
|---|---|---|---|
| Population, n | 550 | 485 | |
| Male | 419 (76.2%) | 355 (73.2%) | .27 |
| Female | 131 (23.8%) | 130 (26.8%) | |
| Mean age, y | 66 | 65 | .569 |
| No. of grafts, mean | 3.7 | 3.9 | .000 |
| Diabetes | 165 (30%) | 123 (25.4%) | .097 |
| LVEF <30% | 63 (11.4%) | 46 (9.5%) | .878 |
| Cerebrovascular disease | 101 (18%) | 42 (8.7%) | .000 |
| Previous CVA | 58 (10.5%) | 23 (4.7%) | .001 |
| Chronic renal insufficiency | 33 (6%) | 23 (4.7%) | .372 |
| Previous CABG | 45 (8.2%) | 49 (10.1%) | .283 |
| PVD | 75 (13.6%) | 48 (9.9%) | .081 |
| Predicted mortality | 2.9% | 3.2% | .224 |
| Incidence left main stenosis | 110 (20%) | 120 (24.7%) | .067 |

*LVEF indicates left ventricular ejection fraction; CVA, cerebrovascular accident; CABG, coronary artery bypass graft; PVD, peripheral vascular disease.

1997-1999, and the OPCABG cohort consisted of 550 consecutive patients who underwent surgery during 1999-2001. Demographic characteristics were generally similar in the 2 groups. The only significant difference was that the off-pump patients had a higher incidence of both cerebrovascular disease and prior stroke.

Conversions to CPB were excluded from the analysis in both groups because we felt that they might unfavorably impact the on-pump group given the likelihood that the conversion was associated with hemodynamic instability not related to the pump run.

### *On-Pump Group*

Surgery was performed while patients were on moderate hypothermic cardiopulmonary bypass (32°C). Heparin was administered to maintain activated clotting times (ACT) above 500 seconds. Cardiac arrest was achieved with antegrade and retrograde cold blood cardioplegia and single aortic cross-clamping for both distal and proximal anastomoses. LV venting was not employed routinely. Anastomoses were performed with running proline sutures. A warm dose of retrograde cardioplegia was given routinely prior to removal of the cross-clamp. Patients were usually extubated within 6 hours after arriving at the intensive care unit.

### *Off-Pump Group*

Patients were kept warm (above 35.5°C) during the procedure. Heparin was administered to maintain activated clotting time (ACT) levels at 300 to 400 seconds unless aprotinin was used, in which case ACT levels were kept above 500 seconds. Stabilization was achieved with several generations of the CTS/Guidant suction/compression stabilizers (Guidant, Santa Clara, CA, USA). Verticalization of the heart was achieved by one of the surgeons (HHB) with deep pericardial sutures. When it became available, the Expose device (Guidant) was used routinely by one of the surgeons (CCQ). Proximal anastomoses were first performed using a partial occlusion clamp after routine epiaortic echo. During the latter part of 2001, the St. Jude Symmetry aortic connector device (St. Jude Medical, Minneapolis, MN, USA) was used for the majority of vein proximal anastomoses. A shunt was placed during performance of the distal anastomoses, usually with a temporary proximal snare to aid in making the initial coronary arteriotomy. A Flo Coil shunt (Guidant) was used for the first part of the series, and a Flo-Thru shunt (Bio-Vascular, St Paul, MN, USA) was used as of early 2001. Shunt sizes varied from 1 mm to 3 mm, depending on the size of the coronary artery. During the last half of 2001, one surgeon (HHB) routinely used interrupted nitinol clips (Coalescent Surgical, Santa Clara CA, USA) for the distal anastomoses. Graft patency was evaluated intraoperatively with transit time ultrasound flowmetry (Transonic Systems, Ithaca, NY, USA). Patients were extubated in the operating room at the discretion of the anesthesiologist (roughly 40% of patients).

Data were collected for all the patients prospectively and entered into our STS database (software by Armus, Burlingame, CA, USA). A retrospective review of the data was performed, focusing on demographic attributes of the 2 cohorts and comparing their in-hospital outcomes.

Nonparametric statistics including Pearson chi square and Fisher exact test were run on categorical data describing patient risk factors and complications. Independent *t* tests were run on population means.

## RESULTS

Preoperative characteristics of the 2 groups are summarized in Table 1. Risk-adjusted predicted mortality assessed using STS criteria was similar in the 2 groups. Also similar were age and gender; incidence of diabetes mellitus, renal insufficiency, and peripheral vascular disease; percentage of patients with a low ejection fraction; and incidence of left main coronary disease and previous CABG. The off-pump group did have a higher risk profile for perioperative stroke, given their statistically significant higher incidence of prior stroke and cerebrovascular disease. The mean number of grafts was only slightly higher in the on-pump group (3.7 off-pump versus 3.9 on-pump).

Early postoperative outcome data for the 2 groups are shown in Table 2. Rates of postoperative stroke, renal failure, blood transfusion, and atrial fibrillation (AF) were found to be significantly higher in the group that underwent CPB. The time spent on mechanical ventilation and duration of postoperative hospital stay were also significantly greater in this group. Rates of mortality, perioperative MI, reoperation for bleeding, and sternal wound infections were not significantly different in the 2 groups. Conversions to CPB were 3.1% for the whole cohort but occurred in only 2 (1.1%) of 173 patients operated on in 2001.

## DISCUSSION

The benefits of avoiding cardiopulmonary bypass in isolated coronary artery grafting have been elucidated in many

Table 2. Early Postoperative Outcomes

| Outcome | Off Pump | On Pump | *P* |
|---|---|---|---|
| Population | 550 | 485 | |
| Postoperative length of stay, d | | | |
| Mean | 5.9 | 7.56 | .000 |
| Median | 5 | 6 | |
| Cerebrovascular accident | 5 (0.9%) | 20 (4.1%) | .001 |
| Postoperative myocardial infarction | 7 (1.3%) | 7 (1.4%) | .810 |
| Mortality | 12 (2.2%) | 19 (3.9%) | .102 |
| Reoperation for bleeding | 4 (0.7%) | 5 (1.0%) | .597 |
| Blood product use | 213 (39%) | 257 (53%) | .000 |
| Atrial fibrillation | 96 (17.5%) | 117 (24.1%) | .008 |
| Renal failure | 13 (2.4%) | 35 (7.2%) | .000 |
| Prolonged ventilator | 20 (3.6%) | 45 (9.3%) | .000 |
| Sternal wound infection | 2 (0.4%) | 3 (0.6%) | .553 |
| Conversions to cardiopulmonary bypass | 17 (3.09%) | | |

studies. Magee and associates reviewed 2 large databases of OPCABG patients in 2 institutions experienced in this technique and found improved early survival with OPCABG [Magee 2002]. Angelini and associates pooled data from their 2 randomized controlled trials of off-pump and on-pump coronary bypass (Beating Heart Against Cardioplegic Arrest Studies [BHACAS] 1 and 2) and found significantly decreased in-hospital morbidity with OPCABG without compromising midterm outcomes [Angelini 2002]. Stamou et al used computer-matched CPB-CABG controls for comparison with a large group of OPCABG patients. Multivariate analysis showed that CPB was associated with a higher in-hospital mortality rate [Stamou 2001].

Our study adds to the growing list of single-institution series of OPCABG surgery. It shows that in centers experienced with this technique, OPCABG can be offered to unselected patients and appears to provide significant improvements in in-hospital morbidity without compromising the completeness of revascularization. We did not demonstrate any differences in mortality between the 2 groups.

The overall incidence of stroke in our OPCABG patients was significantly less despite a higher stroke-risk profile in the OPCABG group. This result has been reported by others [Ricci 2000, Trehan 2001] and can be more uniformly demonstrated in the elderly. The incidence of AF was also unexpectedly lower in the OPCABG group. This result has been documented in other off-pump series as well [Boyd 1999, Ascione 2000, Hernandez 2001]. It is not clear whether this difference in AF contributed significantly to the lower stroke rate in the OPCABG group. We also demonstrated significantly less postoperative renal failure in OPCABG patients, as has been reported in the literature [Loef 2002]. The mechanism of postoperative renal failure in CPB has been related to the inflammatory response and oxidative stress, which are diminished in OPCABG [Gerritsen 2001]. Probably the most consistent finding in studies comparing OPCABG to CPBCABG has been that there is significantly less use of blood products in OPCABG [Ascione 2001], a characteristic that has also been our experience in this study.

The technical aspects of OPCABG have also been well elucidated over the last 5 years. Techniques for exposing and stabilizing the coronary targets, maintaining intraoperative hemodynamic stability, and verifying graft patency have all been addressed in the literature [Baumgartner 1999, Hart 1999].

Refinements in the actual grafting process are now the challenge in most centers that are experienced in OPCABG. The possibility of endothelial damage during off-pump grafting is a valid concern. Such damage can be related to snaring of the proximal coronary artery, the use of $CO_2$ blowers [Demaria 2001, Okazaki 2001], and the placement of shunts. We feel that that the use of shunts minimizes the possible damage from snares and significantly lessens the need for continuous $CO_2$ blowers. This result has also been noted by Rivetti et al [1998]. Shunts have been shown to reduce transient intraoperative myocardial dysfunction, especially when used in grafting of the right and circumflex coronary artery branches [Yeatman 2002]. Dapunt et al have demonstrated in a porcine model that the use of an intracoronary shunt minimizes myocardial stunning secondary to ischemia reperfusion after 15 minutes of left anterior descending artery (LAD) occlusion during LAD grafting [Dapunt 1999].

Many of the earlier reports on OPCABG have documented its safety and efficacy in selected groups of patients receiving a low number of grafts [Lancey 2000, Bull 2001, Kirk 2001, McKay 2001]. Our series shows that this technique can be offered to all patients without compromising the number of grafts or the completeness of revascularization. We think that the routine use of shunts is beneficial in this regard. More recent studies including series of high-risk patients with LV dysfunction [Trehan 2001] and left main coronary disease [Yeatman 2001] have been published and show good outcomes with routine intracoronary shunting.

The current study has the significant drawback of not being a prospective randomized study. However, we think that the results reflect a real difference in outcomes given the size of the cohort, the similarity in the 2 patient populations, and the fact that the patients were operated on by the same surgeons at one institution within a 5-year time frame. Given the fact that this series includes an obligatory learning curve, we think that our experience shows the possibility of adopting a totally off-pump program with good short-term outcomes. We did not address graft patency in this review but did not see any differences in perioperative ischemic events or readmissions for ischemia in the short term. Long-term follow-up is obviously necessary to validate late outcomes.

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