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Coronary Artery Bypass Grafting: An Off-Pump versus On-Pump Review

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Abstract: There has been a proliferation in the number of coronary artery bypass grafts (CABG) being performed without the use of cardiopulmonary bypass (CPB). However, the benefits of off-pump coronary artery grafting (OPCAB) are still being determined. The aim of this retrospective review was to compare the perioperative outcomes of CPB patients with OPCAB patients and to identify the patients most likely to benefit from the off-pump procedure. We reviewed the perioperative data of all isolated CABG patients at two metropolitan hospitals for the period of August 2000 to September 2001. The two groups (OPCAB vs. CPB) were further divided into subgroups identifying patients by their predicted mortality (higher-risk and lower-risk) and the number of distal graft anastomoses received (1, 2, 3, 4, or 5). A p value less than .05 was considered significant. Out of the total of 882 patients, 46.2% were OPCAB cases. Both CPB and OPCAB groups were similar in terms of demographics and predicted risk of mortality. Intraoperatively, OPCAB patients had fewer distal graft anastomoses (2.4 ± 1.0 vs. 3.2 ± 1.0, $p < .001$). Postoperatively, patients in the OPCAB group had less chest drainage (889 ± 588 vs. 989 ± 662 mls, $p < .001$), sustained fewer strokes (0.2 vs. 1.9%, $p < .05$), were transfused less (15.4 vs. 32.5%, $p < .001$) and were discharged earlier (7.3 ± 5.6 vs. 8.5 ± 9.1 days, $p < .05$). For higher-risk patients, OPCAB was associated with fewer reoperations for bleeding (1.3 vs. 6.4%, $p < .05$), a lower stroke rate (0 vs. 3.2%, $p < .05$), and a trend toward lower mortality (7.1 vs. 15.1%, $p = .08$). However, lower-risk OPCAB patients' stroke incidences (0.5% OPCAB group vs. 1.4% CPB group), and mortality rates (0.5 vs. 0.5%) were similar. Comparisons by number of grafts performed revealed that only the single-grafted OPCAB patients had statistically fewer postoperative complications, reduced chest drainage, and a shorter intensive care stay. Differences between either operation groups in transfusion rates were only statistically significant for the one to three grafted patients, while postoperative stays were similar for patients having four grafts. These results suggest that OPCAB is associated with a reduction in mortality and morbidity, particularly within the higher-risk patients. However, the benefits of OPCAB diminished with an increasing number of distal anastomoses performed. **Keywords:** coronary artery bypass grafting, cardiopulmonary bypass, off-pump coronary artery bypass surgery. *JECT. 2002;34:260–266*

Introduction of the DeWall–Lillehei bubble oxygenator in 1956 opened up the practice of cardiac surgery. Since then, heart surgery using cardiopulmonary bypass (CPB) has been extensively performed worldwide (1). CPB allows the heart to be arrested, thereby providing a motionless and bloodless field to enable optimal and complete coronary artery bypass grafting (CABG).

However, CPB has been implicated in postoperative morbidity because of the exposure of the patient's blood to foreign surfaces, impaired perfusion to the heart and lungs, alteration in perfusion to the rest of the body, and the generation of emboli (2). CPB-associated morbidity is becoming more of an issue as cardiac operations are being performed on older and higher-risk patients (3).

Attempts to decrease this morbidity and reduce hospitalization have resulted in the interest in performing CABG on the beating heart without CPB (4). Faster hospital recovery associated with reductions in mortality, strokes, postoperative blood loss, and the need for blood transfusions have all been cited (5,6).

Off-pump coronary artery bypass (OPCAB) is technically more demanding because of the constant heart motion. Furthermore, cardiac output may be impaired while the heart is being manipulated to allow for surgical access. Subsequently, there are concerns about the quality of the anastomosis, the completeness of revascularization, and the ability of the patient to tolerate periods of hemodynamic compromise (7). Therefore, determining which of the two procedures would be most appropriate for a pa-

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tient is still being resolved. The patient's age, comorbidity, and coronary anatomy are factors that must be considered.

The aim of this retrospective review was to compare the perioperative outcomes of CPB patients with OPCAB patients and to identify the patients most likely to benefit from the off-pump procedure. This was undertaken by examining the data of all isolated CABG patients at two metropolitan hospitals for the period of August 2000 to September 2001.

METHODS

Patients

All patients who underwent isolated CABG at two metropolitan hospitals in Sydney, Australia, between August 2000 and September 2001 were retrospectively reviewed. Of a total of 882 patients, there were 474 CPB and 408 OPCAB cases. Both institutions used the same surgeons, anesthetists, perfusionists, and intensivists. The decision to perform the operation on-pump or off-pump was made by the operating surgeon. All surgeons were familiar with the OPCAB procedure since 1998 and had, therefore, progressed beyond the learning curve stage for a new surgical technique. The proportion of patients who underwent OPCAB rather than CPB by surgeon, varied from 4–95% with the proportion of all CABG cases by surgeon ranging from 9–30%. Using the intention to treat principle, the 13 patients that were converted to on-pump remained in the OPCAB group.

Preoperative risk estimation was prospectively determined using the Parsonnet scoring system whereby various patient risk factors were assigned a score; the sum of the scores being used to derive the estimated risk of mortality from a graph (8). To investigate the influence of predicted risk of mortality on outcomes, each operation group was further divided into approximately two equal groups based on the median of the predicted risk of mortality scores (1.8%): "lower-risk" (predicted mortality ≤ 1.8%; 207 CPB and 186 OPCAB patients) and "higher-risk" (predicted mortality > 1.8%; 188 CPB and 155 OPCAB patients). Not all patients were scored for risk ($N = 146$) and thus could not be included in risk calculations. To control the number of distal anastomoses, patients were compared by the number of distal anastomoses performed (one to five: as only eight CPB patients and one OPCAB patient had more than five distal anastomoses, they were excluded from this comparison).

Outcome

Preoperative parameters analyzed included age, gender, body surface area (BSA), left main coronary artery stenosis greater than 50%, previous history of myocardial infarction, and predicted risk of mortality using Parsonnet scores. Intraoperative data consisted of the number of distal anastomoses performed. Postoperative variables included use of the intra-aortic balloon pump (IABP), total chest drainage, blood transfusion incidence, intubation, and intensive care (ICU) times, postoperative hospitalization, and complication rates. Complications of interest were significant troponin rise as a marker of myocardial infarction (>1.0 microgram/L), new renal failure (doubling in creatinine over preoperative value or >2.0 mmol/L or new requirement for dialysis), stroke (central neurological deficit persisting longer then 72 hours), emergency reoperations for bleeding or regrafting, infections (sternal, conduit harvest site, or septicemia), and death (during hospitalization or within 30 days after the initial operation).

Anesthesia Management

Both OPCAB and CPB patients received the same anesthetic regimen. Premedication consisted of oral lorazepam and intramuscular morphine and metoclopramide. Oxygen was administered by facemask while the patient was induced with fentanyl, pancuronium, and midazolam. Patients were ventilated with 100% oxygen to an end tidal carbon dioxide of 30–35 mmHg. Isoflurane or servoflurane was used for anesthetic maintenance pre- and post-CPB. Total intravenous anesthesia was rarely used.

Anticoagulation Management

Before commencement of CPB, patients were given a bolus dose of 300–400 IU/kg of heparin to achieve a target activated clotting time (ACT) of at least 400 seconds. Additional heparin was infused on CPB if required. In the OPCAB group, 150 IU/kg of heparin was administered before division of the internal mammary artery to maintain an ACT of 250–350 seconds. Following termination of CPB or upon completion of anastomoses in OPCAB patients, protamine was given to reverse the anticoagulant effect of heparin.

OPCAB Operation

OPCAB surgery was performed via a sternotomy incision. Stabilization of the target coronary artery was achieved by using either a compression device (Platypus, Wolfram Surgical Instruments, Croydon, Australia) or suction apparatus (Octopus II, Medtronic, Minneapolis, MN). The target artery was then exposed and snared above the anastomotic site using a soft silicon vascular loop to minimize coronary trauma. Subsequently, the coronary artery was then opened and anastomosed. In selected cases, an intracoronary shunt was used to perfuse the target coronary artery distally during anastomosis. If a proximal graft was anastomosed to the aorta, a partial clamp was used. Normothermia was maintained by placing the patient on a water mattress, applying a warming blanket, warming intravenous fluids and elevating the operating theatre temperature. Operative blood was aspirated into a blood salvaging system to be concentrated, washed, and transfused if enough was collected. A perfusionist remained on standby for emergency institution of CPB if required.

CPB Operation

CPB surgery was performed through a full sternotomy incision using a membrane oxygenator and either a roller or centrifugal pump with a 25 μm arterial filter. The circuit was primed with 2000 mL of Hartman's solution and 10,000 units heparin. Institution of CPB was achieved by cannulating the ascending aorta and right atrium. After cross clamping, antegrade or retrograde blood cardioplegia in a 4:1 ratio was infused to arrest and preserve the heart. Systemic pressures were maintained between 60 and 80 mmHg by metaraminol and isoflurane. Surgeon preference determined the minimum systemic temperatures, which ranged from 28–34°C. Isoflurane was used for anesthetic maintenance during CPB. All cardiotomy blood was returned to the CPB circuit. Surgeon preference also determined if proximal anastomoses were performed with the cross clamp in situ or by a partial aortic clamp.

Postoperative Care

Treatment of both OPCAB and CPB patients followed a standardized care from operation to discharge regardless of the procedure performed.

Data Collection and Statistical Analysis

Patients' characteristics, intraoperative and postoperative information were collected on a datasheet and subsequently entered into a customized Microsoft Access cardiac surgery database by a data manager. Statistical analyses were performed using StatView (StatView; Abacus Concepts, Berkeley, CA) with a p value less than .05 considered significant. Continuous variables were analyzed with unpaired t tests or Mann–Whitney U tests (depending on normality of variable distribution). Categorical data were compared using the χ^2 statistic with Fisher two-tailed exact test used if the expected cell sizes were small ($N < 5$). Data are summarized as the mean ± one standard deviation (SD), unless otherwise indicated.

RESULTS

Both the CPB and OPCAB patients were similar in terms of age, gender, BSA, left main disease, preoperative myocardial infarctions, and number of previous heart operations (Table 1). There was also no difference in the predicted risk of mortality (3.5 ± 6.8% in the CPB group vs. 3.0 ± 5.1% in the OPCAB group, p = NS). The number of distal anastomoses performed was significantly higher in the CPB group (3.2 ± 1.0 vs. 2.4 ± 1.0, $p < .001$).

Table 2 depicts the postoperative data. The OPCAB patients had less chest drainage (889 ± 588 vs. 989 ± 662 mL, $p < .001$), fewer strokes (0.2 vs. 1.9%, $p < .05$), fewer blood transfusions (15.4 vs. 32.5%, $p < .001$), and were discharged earlier (7.3 ± 5.6 days vs. 8.5 ± 9.1 days, $p < .05$). IABP usage trended higher for CPB patients but was not significant (4.2 vs. 2.0%, $p = .057$). Other outcomes showed no significant difference in intubation times, ICU stay, myocardial infarction, reoperation rate for grafting and bleeding, infection, and renal failure. There was a mortality rate of 2% in the OPCAB group as compared with 4.2% for patients undergoing CPB ($p = .057$).

The predicted risk of mortality was similar for both operation types within the lower-risk (1.0 ± 0.4% in the CPB group vs. 1.0 ± 0.5% in the OPCAB group) and higher-risk categories (6.3 ± 9.1% in the CPB group vs. 5.4 ± 6.9% in the OPCAB group) (see Table 3). Both the lower-risk and higher-risk OPCAB patients had shorter postopera-

Table 1. Patient demographics.

Variable	CPB (N = 474)	OPCAB (N = 408)
Gender (female)	22.7%	26.5%
Age (years)	66.3 ± 9.9	66.4 ± 11
BSA (m^2)	1.9 ± 0.2	1.9 ± 0.2
Left main disease ≥50%	14.6%	15.4%
Previous MI	34.6%	29.5%
Redo operations	9.1%	8.6%
Predicted mortality %	3.5 ± 6.8 (1.8)	3.0 ± 5.1 (1.8)

Medians given in parentheses.

Table 2. Post-operative data.

Variable	CPB (N = 474)	OPCAB (N = 408)
Intubated (h)	22.5 ± 72 (9.0)	18.4 ± 55 (9.5)
ICU stay (h)	65.2 ± 74 (48)	64 ± 92 (48)
Postoperative stay (day)	8.5 ± 9.1 (6.6)	7.3 ± 5.6* (5.7)
Troponin rise	5.7%	4.9%
Regrafting	1.7%	1.2%
IABP	4.2%	2%†
Total chest drain. (mL)	989 ± 662 (850)	889 ± 588*** (760)
Re-op for bleeding	3.4%	1.5%
Transfusion	32.5%	15.4%***
Stroke	1.9%	0.2%*
Renal failure	1.1%	0%
Infection	1.5%	1%
Mortality	4.2%	2%†

*$p < .05$.
***$p < .001$.
†$p = .057$.
Medians given in parentheses.

Table 3. Postoperative data—risk stratified.

	Lower Risk		Higher Risk	
Variable	CPB (*N* = 207)	OPCAB (*N* = 186)	CPB (*N* = 188)	OPCAB (*N* = 155)
Predicted mortality %	1.0 ± 0.4 (1.0)	1.0 ± 0.5 (1.0)	6.3 ± 9.1 (3.0)	5.4 ± 6.9 (3.2)
Intubated (h)	14.4 ± 55 (8.0)	15.4 ± 48.7 (8.0)	31.5 ± 94 (12)	24.6 ± 71 (12)
ICU stay (h)	56.1 ± 69 (47)	53.1 ± 38 (47)	80.0 ± 106 (49)	73.8 ± 107 (49)
Postoperative stay (day)	7.1 ± 4 (6.3)	6.3 ± 4.5*** (5.6)	9.9 ± 12.8 (7.4)	8.2 ± 6.2*** (6.5)
Troponin rise	2.9%	2.7%	9.0%	7.7%
Regrafting	1.0%	1.1%	1.6%	1.9%
IABP	0.5%	0%	9.0%	4.5%
Total chest drain (mL)	934 ± 383 (850)	898 ± 635* (800)	1041 ± 877 (875)	867 ± 580** (580)
Re-op for bleeding	1.0%	1.6%	6.4%	1.3%*
Transfusion	17.9%	8.1%**	47.9%	25.2%***
Stroke	1.4%	0.5%	3.2%	0%*
Renal failure	0%	0%	2.1%	0%
Infection	1.0%	1.1%	2.1%	0.6%
Mortality	0.5%	0.5%	15.1%	7.1%‡

*$p < .05$.
**$p < .01$.
***$p < .001$.
‡$p = .08$.
Medians given in parentheses.

tive stays, less chest drainage, and fewer blood transfusions than their risk- equivalent CPB patients. Lower-risk patients' stroke incidences (1.4% CPB group vs. 0.5% OPCAB group) and mortality rates (0.5% CPB group vs. 0.5% OPCAB group) were similar. For the higher-risk patients, OPCAB was also associated with fewer reoperations for bleeding (1.3 vs. 6.4%, $p < .05$), a lower stroke rate (0 vs. 3.2%, $p < .05$), and a trend toward lower mortality (7.1 vs. 15.1%, $p = .08$). Other outcomes for both the higher- and lower-risk patients showed no significant difference in intubation times, intensive care stay, myocardial infarction, IABP use, reoperation rate for regrafting, renal failure, and infection.

When controlling for the number of distal anastomoses, the higher morbidity and mortality of CPB diminished with an increasing number of distal anastomoses performed (Table 4). The predicted mortality between the CPB and OPCAB patients was not significantly different within each of the distal anastomoses categories despite the single graft CPB group having a higher mean predicted risk (10.9 ± 18 vs. 2.3 ± 2.1%, p = NS). Differences in mortality only approached significance within the single-graft group: CPB 2/16 (12.5%) vs. 1/98 (1%) for OPCAB ($p = .051$). Only the single-grafted OPCAB patients had fewer reoperations for bleeding and re-grafting (0 vs.13.3%, $p < .05$), reduced chest drainage (753 ± 380 vs. 1305 ± 1000 mL, $p < .05$), less IABP use (0 vs. 12.5%, $p < .05$), and a shorter intensive care stay (48 ± 14 vs. 75 ± 81 hours, $p < .01$). There was a trend toward elevation in troponin levels seen in OPCAB after three distal anastomoses (14.6 vs. 5.2%, $p = .055$). Postoperative hospitalization was consistently longer for CPB patients with the exception of the four-grafted group. Transfusion rates were higher for CPB patients having up to three distal anastomoses; more grafting was not associated with a significant difference in transfusion.

DISCUSSION

Comparison of the perioperative outcomes of CPB patients with OPCAB patients showed that fewer distal graft anastomoses are performed in the OPCAB group. Postoperatively, OPCAB patients have less chest drainage, sustain fewer strokes, are transfused less blood, and are discharged earlier. There is also a trend toward a lower mortality rate for the OPCAB group. Other outcomes found no significant difference in intubation times, ICU stay, evidence of myocardial infarction, reoperation rate for regrafting, new renal failure, and infection.

The patients most likely to benefit from the off-pump procedure are the higher-risk OPCAB patients with fewer reoperations for bleeding, a lower stroke rate, and a trend toward lower mortality. Furthermore, both the higher- and lower-risk patients have shorter postoperative stays, less chest drainage, and fewer blood transfusions. When controlling for the number of distal anastomoses, the benefits of OPCAB diminish with an increasing number of distal anastomoses performed.

Table 4. Patient characteristics by number of distal anastomosis performed.

	One		Two		Three		Four		Five	
Variable	CPB (N = 16)	OPCAB (N = 98)	CPB (N = 80)	OPCAB (N = 130)	CPB (N = 197)	OPCAB (N = 122)	CPB (N = 134)	OPCAB (N = 48)	CPB (N = 33)	OPCAB (N = 7)
Predict mortality %	10.9 ± 18 (2)	2.3 ± 2.1 (1.8)	2.8 ± 4.2 (1.7)	3.3 ± 6.3 (1.5)	4.1 ± 8.4 (1.8)	3.5 ± 6.0 (1.8)	2.9 ± 3.7 (2)	2.7 ± 2.6 (2)	1.9 ± 1.4 (1.5)	1.8 ± 1.2 (1.6)
Re-do operations	37.5%	22.4%	11.3%	6.9%	7.1%	3.3%	7.5%	0%	3.0%	0%
Intubated (h)	47.1 ± 89 (13.5)	11.8 ± 13 (9)	36 ± 137 (9)	14.8 ± 34 (9)	18.2 ± 58 (9)	21.9 ± 67 (9)	18.5 ± 31 (10)	34 ± 112 (12)	18.7 ± 24 (9)	11.2 ± 15 (11)
ICU stay (h)	75 ± 81 (49)	48 ± 14.8** (48)	73 ± 132 (47)	63.5 ± 93 (48)	58.6 ± 40 (48)	72 ± 114 (47)	63.4 ± 50 (48)	81 ± 117 (50)	60.1 ± 30 (48)	81 ± 117 (50)
Postop stay (day)	9.0 ± 5.3 (7)	6.2 ± 3.0* (5.6)	7.4 ± 5.7 (6.5)	7.3 ± 5.8‡ (5.7)	8.9 ± 12 (6.6)	8.2 ± 6.9* (6.4)	8.3 ± 5.2 (6.7)	7.6 ± 5.9 (6.5)	7.1 ± 2.7 (6.5)	5.5 ± 2.1* (4.9)
Troponin rise	6.7%	1.0%	3.8%	4.6%	6.6%	4.9%	5.2%	14.6%‡	6.1%	0%
Regrafting	13.3%	0%*	2.5%	1.5%	0.5%	1.6%	1.5%	2.1%	0%	0%
IABP	12.5%	0%*	2.5%	1.5%	3.0%	3.3%	5.2%	4.2%	9.1%	0%
Reop for bleeding	13.3%	0%*	3.8%	1.5%	3.8%	1.5%	3.0%	0%	3.0%	14.3%
Total chest drain. (mL)	1305 ± 1000 (863)	753 ± 380* (700)	926 ± 570 (750)	869 ± 427 (800)	978 ± 780 (875)	980 ± 856 (750)	988 ± 486 (900)	939 ± 393 (825)	1113 ± 569 (950)	1156 ± 757 (800)
Transfusion	40%	8.2%**	33.8%	13.1%***	32.0%	21.3%*	31.6%	20.8	36.4%	28.6%
Stroke	0%	0%	1.3%	0%	1.5%	0.8%	3.0%	0%	0%	0%
Renal failure	6.7%	0%	2.5%	0%	1.0%	0%	0%	0%	0%	0%
Infection	0%	0%	1.3%	1.5%	1.5%	0%	2.2%	2.1%	0%	14.3%
Mortality	12.5%	1%†	5.0%	1.5%	2.5%	2.5%	3.0%	2.1%	12.1%	14.3%

*$p < .05$.
**$p < .01$.
***$p < .001$.
†$p = .051$.
‡$p = .055$.
Medians given in parentheses.

The significantly fewer distal anastomoses performed in the OPCAB patients are commonly reported in OPCAB vs. CPB comparisons (9–11). This phenomenon needs to be considered when reviewing postoperative mortality and morbidity. Many postoperative differences between OPCAB and CPB were ameliorated when considered by graft number except for single-grafted patients. Despite the predicted risk not being significantly different, there is evidence that the OPCAB and CPB single-graft patients were not equivalent groups; the large SD indicates that several very high-risk CPB patients were responsible for the significantly higher morbidities and mortality. Furthermore, it is now unusual to perform a single graft on CPB on a low-risk patient in our institutions.

An increased stroke rate was associated with the higher-risk CPB patients. High-risk patients have an increased threat of stroke because of the effects of cerebral macroembolization or ischemic hypoperfusion of CPB being exacerbated by their increased age, comorbidities, and tendency to have longer bypass times (12). A recent retrospective analysis of 126 centers using the Society of Thoracic Surgeons National Adult Cardiac Surgery Database revealed a reduction in the risk of stroke from 4.6%–2.5% when using OPCAB vs. CPB for patients having preexisting cerebrovascular disease (5).

Shorter postoperative hospitalization was a consistent feature of our OPCAB patients. Both Hernandez et al. (1741 OPCAB patients vs. 6126 CPB patients) and Plomondon et al. (680 OPCAB patients vs. 1733 CPB patients) described a median postoperative reduction of one day for OPCAB in their large multicenter reviews (9, 11). However, our ventilator and ICU times were similar for the two operation types. It maybe that our standardized anesthetic regimen and a similarity in ICU protocols for both groups of patients thwarted the full potential of earlier extubations and ICU transfers in the OPCAB group as reported by others (13,14).

The differences in mortality were limited to the higher-risk CPB patients, suggesting that this group benefited from OPCAB. However, when controlling for graft number, differences in mortality between the two procedures attenuated with the exception of the single-grafted group. Cleveland et al. showed that OPCAB reduces risk adjusted mortality across all risk groups; whereas, Arom et al. observed significant differences in mortality within their high-risk group only (5,13).

Postoperative blood loss was higher in the CPB patients; an observation made by others (5,13). This increased bleeding may be attributed to the inflammatory and coagulopathic sequelae of CPB. The higher transfusion rates for CPB patients are well documented (6,15) but were not necessarily associated with increased blood losses in our study. Both two- and three-grafted CPB patients had similar blood losses and reoperation rates for bleeding as their OPCAB cohort, yet continued to have a significantly higher transfusion rate. A contributing factor may be hemodilution-induced anemia because of the crystalloid prime of CPB.

New renal failure was not observed in the OPCAB group being apparently represented within the higher-risk CPB only. The reduction in the likelihood of higher-risk pre-existing acute renal failure patients developing further renal dysfunction has been demonstrated in OPCAB (13,16). Enhanced renal protection may be seen in OPCAB patients because of lack of inflammatory processes and pulsatile blood flows (17).

Rates of infection were similar for both OPCAB and CPB groups despite blood transfusion-associated immunosuppression and the exposure of blood to the foreign surfaces of the cardiopulmonary bypass circuit (18).

Evidence of myocardial insufficiency was suggested by the higher incidence of IABP usage for CPB patients, especially within the higher-risk group. This may be a reflection of a selection bias, whereby patients with impaired myocardial function were selected into the CPB group, or it may indicate increased myocardial trauma associated with the CPB procedure. Troponin rise was equivalent in both groups, mutually elevated in the higher-risk patients. With the exception of the higher elevation in troponin seen in the four-grafted OPCAB patients, all graft numbers had statistically similar troponin rises between the groups. Cross clamping and cardioplegia results in the leakage of myocardial troponin (19) but so may the cardiac elevation, intermittent coronary artery occlusion, hypotensive episodes, and venous congestion associated with OPCAB (7).

Whether the OPCAB cases were presenting with fewer diseased coronary arteries or were not being fully revascularized cannot be addressed in this study, because the number of diseased vessels was not quantified. The surgical gold standard has been to revascularize completely using cardiopulmonary bypass based on its beneficial effect on event-free survival (20). Furthermore, issues regarding the quality of the anastomosis performed on a beating heart remain to be resolved. Angiographic studies undertaken in the early postoperative period yielded satisfactory graft patencies (10). However, as early as within one year postoperatively, evidence of increasing angina and re-interventions were seen (13). In the 7-year follow-up by Gundry et al., there was a threefold increase in reinterventions for OPCAB patients (21). Nevertheless, incomplete revascularization in older higher-risk patients may be rationalized as a palliative procedure (22). Longer-term survival is less relevant than short-term relief from angina, especially when the OPCAB technique may the appropriate procedure for those elderly, high-risk patients with an unacceptably excessive morbidity risk if operated on using CPB.

The future role of OPCAB is still being addressed. Its application in the higher-risk patients merits attention, particularly in those previously considered inoperable. However, not only is the population aging, it is healthier; a 60-year-old now expects a longer longevity of the benefits offered by CABG. Fully revascularizing the heart under the ideal surgical conditions provided by cardiopulmonary bypass has yet to be disproved as the treatment of choice for longer-lasting improvement in quality of life. Until the results of the prospective randomized longer-term multicenter studies become available, surgeons and patients must reconcile a potential operative morbidity and predictable improvement in quality of life, with a potential reduction in shorter-term operative morbidity and unresolved longer-term freedom from cardiac events.

In summary, this review shows that OPCAB is associated with a reduction in mortality and morbidity, particularly among the higher-risk patients. However, the benefits of OPCAB diminished with an increasing number of distal anastomosis performed.

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