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Reoperative Coronary Artery Bypass Grafting With and Without Cardiopulmonary Bypass: Determinants of Perioperative Morbidity and Mortality

Dr. D'Ancona

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Giuseppe D'Ancona, MD,[1] Hratch Karamanoukian, MD,[1] Marco Ricci, MD,[2] Tomas Salerno, MD,[2] Thomas Lajos, MD,[1] Jacob Bergsland, MD[1]

[1]The Division of Cardiothoracic Surgery at Buffalo General Hospital and State University of New York at Buffalo, Buffalo, New York
[2]University of Miami Medical School at Jackson Memorial Hospital, Miami, Florida

ABSTRACT

Background: This retrospective study evaluates perioperative results of reoperative coronary artery bypass grafting (CABG) with and without cardiopulmonary bypass (CPB).

Methods: From January 1995 to March 1999 reoperative CABG was performed on 581 patients: 307 (52.84%) patients were operated upon on-CPB and 274 (47.16%) off-CPB. Median sternotomy was used in all patients on-CPB. Median sternotomy or alternative surgical approaches were used in the off-CPB group. Data was retrospectively reviewed. To identify the variables independently related to perioperative mortality and adverse outcome, multivariate analysis was performed in the overall population of 581 patients.

Results: Preoperative risk factors were comparable in the two groups. Critical lesions of the right and left circumflex coronary artery were more common in the on-CPB group ($p < 0.005$). A total of 2.7 grafts/patient was performed in the on-CPB group versus 1.3 grafts/patient in the off-CPB group (p = NS). Freedom from postoperative complications was higher in the off-CPB group (72% versus 90.9%, $p < 0.005$). Perioperative stroke and respiratory failure rates were more common in the on-CPB group (3.9% versus 0.7% and 5.9% versus 2.2% respectively, $p < 0.005$). Actual mortality was 5.9% in the on-CPB group and 3.6% in the off-CPB group (p = NS). Risk adjusted mortality was 2.2% and 1.3% in the on-CPB and off-CPB groups respectively. Although CPB was found to be independently related to adverse outcome (odds ratio (OR) = 2.89, p-value < 0.005), no correlation was found between mortality and CPB.

Conclusions: Avoidance of CPB independently reduces adverse outcomes in reoperative CABG without affecting mortality rate.

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Address correspondence and reprint requests to: Hratch Karamanoukian, MD, Kaleida Health-Buffalo General Hospital Site, 100 High Street, Buffalo, NY 14203, Phone (716) 859-1080, Fax (716) 859-4687, Email: lisbon5@yahoo.com

INTRODUCTION

The incidence of reoperative CABG has progressively increased to the point that over 10% of all adult cardiac surgical procedures performed in New York State are reoperations [Hannan 1990]. Reoperative CABG carries a high mortality rate, ranging from 3 to 12% [He 1995] and, for this reason, alternative strategies have evolved over the last few years aimed at reducing its operative risks. Alternative surgical techniques to limit graft and aortic manipulation ("no-touch" technique) and to enhance myocardial protection have enriched the surgical armamentarium of reoperative CABG [Savage 1994]. Avoidance of CPB has recently emerged as an effective strategy to further reduce the complications encountered during surgery for recurrent coronary artery disease (CAD) [Calafiore 1996, Boonstra 1997].

This report recounts our experience in reoperative CABG performed with and without CPB and evaluates whether avoidance of CPB may, independently, improve perioperative outcome in this selected group of patients.

MATERIALS AND METHODS

Reoperative CABG was performed on 581 patients from January 1995 to March 1999. A total of 307 patients (52.84%) were operated upon on-CPB and 274 (47.16%) off-CPB. Patients were included in one of the two groups based on different referral patterns. A traditional approach with median sternotomy was mainly performed in the on-CPB group to achieve simultaneous revascularization of the three main coronary artery territories (left anterior descending (LAD), right coronary artery (RCA), and circumflex). By contrast, the off-CPB approach was preferred in the context of limited coronary artery disease amenable to revascularization with median sternotomy or alternative surgical incisions. Standard techniques of aortic and right atrial cannulation were used for institution of CPB. In the majority of the on-CPB patients, myocardial protection was achieved by means of ante-grade/retrograde intermittent cold blood cardioplegia. Mild systemic hypothermia (32°C) was mainly used in that group. Distal and proximal anastomoses were performed in the usual fashion with 7-0 and 6-0 prolene running sutures. Surgical technique and surgical approaches adopted in the off-CPB group are summarized in the following paragraphs.

SURGICAL TECHNIQUE: OFF-CPB

Median sternotomy approach

Complete revascularization of the heart via median sternotomy was achieved off-CPB in 122 reoperations. After median sternotomy with an oscillating saw, lysis of adhesions was performed starting from the diaphragmatic portion of the pericardium. Particular care was taken to minimize manipulation of old grafts, aorta, and heart. LAD exposure was achieved by elevating the heart with a laparotomy pad placed in the posterior pericardium. Exposure of the RCA and its terminal coronary branches was obtained by retracting the acute margin of the heart with a stay suture placed in the epicardium. Exposure of the circumflex system was achieved by placing the "single suture" in the oblique sinus of the pericardium, as previously described [Bergsland 1999]. Once optimal exposure was reached, the stabilizer foot (CTS, Cupertino, CA) was positioned on the target coronary artery, and a 4-0 prolene pledgetted suture was used to proximally snare the vessel. The proximal snare was used to obtain ischemic preconditioning (3 minutes) before performing the arteriotomy and to control bleeding while positioning the intracoronary shunt. Intraoperative graft patency verification was routinely performed via transit time flowmeter (TTFM, Medistim, Oslo, Norway) upon completion of distal anastomoses.

Left anterior small thoracotomy (LAST)

The LAST procedure [Calafiore 1996] was used in 48 consecutive patients for reoperative CABG to the LAD. Difficulty in harvesting the mammary artery through a small thoracotomy makes the LAST procedure technically more demanding than a median sternotomy approach. In our series, conversion to median sternotomy (one case) was due to dense pleural adhesions. Furthermore, conversion to sternotomy may be necessary for better visualization of an intramuscular or diffusely diseased LAD [Calafiore 1996]. In contrast, a right anterior small thoracotomy (RAST) was used in two reoperative cases to revascularize the RCA with the right internal mammary artery (RIMA). In the presence of an old patent vein graft to the LAD, the left internal mammary artery (LIMA) can be harvested and anastomosed to a marginal branch of the circumflex coronary artery if needed. In this case the incision is extended posteriorly into a full thoracotomy. This approach was used in four patients reoperated on for recurrent CAD involving the circumflex territory.

The "H" graft

Dense pleural adhesions are commonly found in reoperations via the left chest and, when this is encountered, construction of an "H" graft, as described by Cohn et al. [Cohn 1998], can be an effective alternative to revascularize culprit lesions without CPB. After harvesting 5 cm of LIMA via a small left anterior thoracotomy in the fifth intercostal space, the artery is clamped proximally and an anastomosis is constructed between a segment of saphenous vein (SVG) and the LIMA in an end-to-side fashion. The terminal part of the LIMA is ligated. The SVG is then anastomosed to the LAD in an "H" graft configuration. In our series, this technique was used in three reoperative CABGs.

Posterior thoracotomy

The posterior thoracotomy approach is suited for patients with CAD limited to the lateral wall of the heart. This approach was first used in 1971 employing femoral cannulation for CPB [Grosner 1990]. In the last several years at our institution, CPB has been eliminated in the majority of cases while maintaining the original conceptual framework of this surgical approach in 59 patients requiring reoperative CABG for CAD limited to the lateral wall of the heart. Patient positioning was as for a standard left posterolateral thoracotomy. An incision was then made 4 cm below the tip of the scapula towards the left mid-axillary line and was extended posteriorly towards the spine. The chest was entered through the sixth intercostal space after dividing the latissimus dorsi muscle and opening the thoracic fascia. The left lung was collapsed and the pericardium was opened. In our experience, this exposure provided access to all branches of the circumflex system. Stay sutures were placed on the pericardium and diaphragm to improve exposure. Once the target site had been selected, on either the native coronary or the hood of an old SVG, intravenous heparin was administered. At this point, after positioning the stabilizer, proximal snaring was achieved with a 4-0 prolene pledgetted suture. After three minutes of ischemic preconditioning, an arteriotomy was performed. Upon completion of the distal anastomosis, the SVG was anastomosed proximally to the descending thoracic aorta.

Table 1. Demographics and preoperative risk factors in 581 reoperative CABGs

	Off-CPB (%)	On-CPB (%)	P-value
Total Patients	274 (47.2)	307 (52.8)	
Male/Female	209/65	246/61	
Age	66.8 (41-85)	65.5 (37-85)	
EF	47% (13-84)	47.8% (10-76)	
Elective	152 (55.5)	136 (44.3)	< 0.05
Urgent	114 (41.6)	152 (49.5)	
Emergent	8 (2.9)	19 (6.2)	
Preop Stroke	27 (9.9)	32 (10.4)	
Calcified AscAorta	10 (3.6)	12 (3.9)	
Diabetes Mellitus	60 (21.9)	82 (26.7)	
Hypertension	213 (77.7)	229 (74.6)	
COPD	80 (29.2)	73 (23.8)	
CHF	28 (10.2)	21 (6.8)	
CRF (Creat > 2.5)	6 (2.2)	1 (0.3)	
Dialysis	4 (1.5)	1 (0.3)	
Preop IABP	4 (1.5)	25 (8.1)	< 0.05
Preop IV NTG	71 (25.9)	75 (24.4)	

EF = ejection fraction, COPD = chronic obstructive pulmonary disease, CHF = congestive heart failure, CRF = chronic renal failure, IABP = intra-aortic balloon pump, NTG = nitroglycerin

Subxiphoid access

The posterior wall of the heart can be approached via a subxiphoid incision. In this case, the graft of choice for isolated posterior coronary artery revascularization is the pedicled right gastroepiploic artery (RGEA). In reoperations this approach limits the hazards of a sternal reentry and reduces excessive manipulation of the heart and aorta [Grandjean 1996, Akhter 1997]. In our series this technique was adopted in 27 redo operations with atherosclerotic disease limited to the RCA or its terminal branches. A midline incision from the lower fourth portion of the sternum to 10 cm below the xiphoid was made, the xiphoid process was excised, and the lower fourth of the sternum was divided using an oscillating saw. The diaphragmatic surface of the heart was dissected, isolating the target vessels, i.e., the RCA before its bifurcation and its terminal branches. After locating the target vessel, the RGEA was harvested. An adequate pedicle was obtained by harvesting the vessel towards the pylorus. The artery was divided and was then passed into the pericardium through a small opening in the central tendon of the diaphragm. Distal anastomoses were performed using standard techniques as described above.

"Hybrid approach": LAST and subxiphoid access, LAST and posterior thoracotomy, LAST and subclavicular incision

Combined surgical approaches were used in a limited number of patients to reach, simultaneously, different target areas of myocardium.

Table 2. Angiographic findings in 581 reoperative CABGs

	Off-CPB	On-CPB	P-value
LM	21 (7.7%)	15 (4.9%)	NS
Prox-LAD	167 (60.9%)	239 (77.9%)	< 0.005
Dist-LAD	67 (24.5%)	89 (29%)	NS
RCA	215 (78.5%)	262 (85.3%)	< 0.05
LCX	161 (58.8%)	245 (79.8%)	< 0.005

LM = left main, LAD = left anterior descending, RCA = right coronary artery, LCX = left circumflex

Proximal anastomoses

To reduce the risks of manipulation of the aorta and old patent grafts, proximal anastomoses were performed to the innominate artery in 12 cases [Ricci 2000], to the right subclavian artery in two cases, and to the left subclavian artery in two cases.

DATA COLLECTION AND STATISTICAL ANALYSIS

Patient information, including preoperative data and perioperative and postoperative morbidity and mortality rates was collected by trained personnel, using the indications of the New York State Database form (Form DOH-225a). Data collected for both study groups were statistically analyzed and compared. Differences between variables were considered significant when the p-value was less than 0.05. Discrete and continuous variables were compared using the χ^2 test and the student t-test, respectively. Multivariable stepwise logistic regression analysis was done to determine the preoperative and intraoperative variables independently related to perioperative mortality, cerebrovascular accident (CVA), and adverse outcome (i.e., any possible perioperative complication, mortality excluded). Operative technique (i.e., use or avoidance of CPB) was considered as one of the variables in the study. Odds ratio (OR) and p-values were evaluated.

RESULTS

A total of 581 patients were included in the study. Preoperative data are summarized in Table 1 (◉). All patients had had at least one operation for coronary artery disease. Operative priority was different in the two groups, the number of elective cases being significantly higher in the off-CPB group (on-CPB 44.3% versus off-CPB 55.5%, $p < 0.05$). Preoperative use of intra-aortic balloon pump (IABP) was more common in the on-CPB group (on-CPB 8.1% versus off-CPB 1.5%, $p < 0.005$). Extent of coronary artery disease was also different in the two groups, critical lesions of LAD, RCA, and left circumflex being more common in the on-CPB group (on-CPB 77.9% versus off-CPB 60.9% for LAD, on-CPB 85.3% versus off-CPB 78.5% for RCA, and on-CPB 79.8% versus off-CPB 58.8% for left circumflex, $p < 0.05$)

Table 3. Surgical approaches in 274 reoperative CABGs off-CPB

	Number of patients	%
Sternotomy	122	44.5%
LAST+RAST	50	18.2%
Posterior thoracotomy	59	21.5%
Subxiphoid with RGEA	27	9.8%
Hybrid procedures	16	5.8%

LAST = left anterior small thoracotomy, RAST = right anterior small thoracotomy, RGEA = right gastroepiploic artery

Table 4. Postoperative morbidity and mortality in 581 reoperative CABGs

	Off-CPB(%)	On-CPB(%)	P-value
Number of grafts/patient	1.3	2.7	
Freedom from complications	249 (90.9)	221 (72.0)	< 0.005
Stroke	2 (0.7)	12 (3.9)	< 0.05
Transmural MI	8 (2.9)	15 (4.9)	
Sternal infections	0 (0)	1 (0.3)	
Wound infections	2 (0.7)	4 (1.3)	
Renal failure	3 (1.1)	11 (3.6)	
Respiratory failure	6 (2.2)	18 (5.9)	< 0.05
Sepsis	2 (0.7)	7 (2.3)	
Reop for bleeding	3 (1.1)	5 (1.6)	
In hospital stay	7.2 (days)	9.8 (days)	
Actual mortality	10 (3.6)	18 (5.9)	
Expected mortality	6.9	6.6	
Risk-adjusted mortality	1.3	2.2	

(Table 2, ◎). Median sternotomy was used in 307 patients (100%) operated upon on-CPB. In the off-CPB group, median sternotomy was used in only 122 patients (44.5%). The following alternative surgical approaches were adopted in the remaining 152 patients (55.5%): left and right anterior small thoracotomy (LAST and RAST) in 48 and two cases respectively (18.2%), left posterior thoracotomy in 59 cases (21.5%), subxiphoid access with harvesting of the RGEA in 27 cases (9.8%), and hybrid approaches in 16 patients (5.8%). Table 3 (◎) summarizes the different surgical approaches adopted in the off-CPB group. Graft/patient ratio was 2.7 in the on-CPB group and 1.3 in the off-CPB group (p = NS) (Table 4, ◎). In six cases (2.1%), conversion to CPB was required as a result of hemodynamic instability. Conversion to median sternotomy was necessary for one patient undergoing a LAST procedure (2%) and for two patients undergoing a subxiphoid approach (7.4%), due to poor quality of the harvested conduits (LIMA and RGEA).

Mortality and morbidity rates are reported in Table 4 (◎). Freedom from overall complications was significantly higher in the off-CPB group (on-CPB 72% versus off-CPB 90.9%, $p < 0.005$). Perioperative stroke rate was higher in the on-CPB group (on-CPB 3.9% versus off-CPB 0.7%, $p < 0.005$). Postoperative respiratory failure was also more common in the on-CPB group (on-CPB 5.9% versus off-CPB 2.2%, $p < 0.05$). A trend for a lower rate of perioperative acute myocardial infarction, wound infection, reoperation for bleeding, post-operative sepsis, and renal failure was recorded in the off-CPB group (Table 4, ◎). Actual mortality was 5.9% in the CPB group and 3.6% in the off-CPB group (p = NS). Risk adjusted mortality was 2.2% in the CPB group and 1.3% in the off-CPB group.

The observed/expected mortality ratio (O/E) was 0.89 in the CPB group and 0.52 in the off-CPB group. Because the two groups were not randomized and differently selected, a logistic regression model was used to determine which variables independently related either to mortality, perioperative stroke, or adverse outcome. Among the many variables considered in the analyses we also included the surgical technique (on-CPB or off-CPB), the different surgeons performing the operations, the surgical priority, and the extent of CAD. Only advanced age, peripheral vascular disease, preoperative congestive heart failure, and number of coronary grafts performed was shown to be independently correlated to mortality (Table 5, ◎). Preoperative CVA, calcification of the ascending aorta, and number of coronary grafts performed were found to be the only covariables independently related to perioperative CVA (Table 5, ◎). CPB was the strongest independent variable correlated to perioperative adverse outcome, with an odds-ratio (OR) of 2.89 (Table 5, ◎).

DISCUSSION

The referral pattern for CABG is changing, and an ever-increasing proportion of patients who present for coronary revascularization are at higher risk due to advanced age, comorbidities, and recurrent CAD after previous bypass surgery [Bergsland 1998]. It has been estimated that 17% of the patients who have previously undergone CABG will need reoperation within 12 years [He 1995]. For this reason, attention has been focused on alternative strategies of myocardial revascularization in order to circumvent the deleterious complications of reoperative CABG by improving techniques of myocardial protection and reducing manipulation of the heart, aorta, and old grafts. During reoperations, amelioration of cardioplegia delivery can be achieved with retroperfusion of the coronary sinus in conjunction with antegrade cardioplegia [Buckberg 1989, Calhourn 1990, Loop 1990], reducing mortality rates to levels as low as 3.4% [Lytle 1987]. Similarly, use of a variety of surgical techniques, such as "no-touch" dissection and single aortic cross-clamping, have been shown to independently reduce operative mortality [Salerno 1982, Aranki 1994, Savage 1994]. However, CPB remains an important determinant for morbidity, including bleeding, thromboembolism, and temporary or permanent organ dysfunction [Butler 1993, Ohata 1997, Edmunds 1998]. Avoidance of CPB for CABG has therefore been proposed as an alternative to traditional methods of myocardial revascularization [Buffolo,

Benetti 1991]. Prospective randomized trials have documented the advantages offered by off-pump CABG in terms of reduced inflammatory response [Ascione 2000], reduced renal and myocardial impairment [Ascione 1999a, Ascione 1999b], decreased blood products usage [Kshettry 2000], and limited neurocognitive impairment [Diegeler 2000].

If initial results in the overall population of surgical candidates are encouraging, patients with high preoperative risk profile may experience an even greater benefit [Pfister 1992, Moshkovitz 1995, Arom 2000]. In this regard, Pfister and co-workers [Pfister 1992] reported their experience in a retrospective, matched-controlled study suggesting that certain groups of patients—those with severely impaired LVEF, women, hypertensives, and especially the elderly and reoperative CABGs—may garner marked advantage from the off-pump technique [Pfister 1992]. In a more recent retrospective analysis of high-risk patients, Moshkovitz et al. [Moshkovitz 1995] have shown that reoperative surgery is not an independent predictor of mortality during off-pump coronary surgery.

To further reduce the risks of reoperative CABG, alternative surgical approaches have also been proposed to revascularize, off-CPB, target coronary artery branches in order to limit the hazards related to resternotomy, manipulation of the aorta, and old grafts. Boonstra et al. [Boonstra 1997] first suggested the use of the LAST procedure with anastomosis of the LIMA to the LAD to treat recurrent CAD involving the LAD. The same group earlier reported the use of the RGEA off-CPB for isolated lesions of the RCA system [Grandjean 1996]. Fonger et al., Fanning, and Baumgartner [Fanning 1993, Fonger 1997, Baumgartner 1999] proposed a posterior right thoracotomy to treat, off-CPB, recurrent and isolated lesions of the circumflex system. Miyaji et al. [Miyaji 1999] demonstrated comparable results between primary and reoperative CABGs performed off-CPB. Allen et al. [Allen 1997] showed a significant decrease in the rate of atrial fibrillation, number of transfusions, and ICU length of stay when comparing a group of patients reoperated upon via LAST with a group of conventional redo operations with disease limited to the LAD. Similarly, Stamou et al. [Stamou 2000] have recently shown significantly reduced mortality, morbidity rates, and length of hospitalization in a limited group of single-vessel reoperative CABGs performed with and without CPB.

Our findings at univariate analysis should be interpreted with caution, as patients were selected differently in the two study groups. Although the on-CPB patients might provide at best the equivalent of an historical control, the logistic regression model is useful to determine the independent risk factors for mortality, CVA, and adverse outcome. Operative mortality in reoperative CABG varies between 3.4% and 12.5%, with a median of 8% [Lytle 1987, Loop 1990, Aranki 1994, Savage 1994, He 1995]. Our mortality rates in the on-CPB (5.9%) and off-CPB (3.6%) groups seem to be very encouraging and in line with the STS value (mortality rate 7.7% for the year 1997). In our study the only determinants for operative mortality after redo CABG were advanced age, peripheral vascular disease, congestive heart failure, and number of performed grafts. Interestingly, CPB did not independently correlate to perioperative mortality. Similarly, Stamou et al. [Stamou 2000] did not find an independent relationship between CPB and perioperative mortality in redo CABG. Other authors have reported different results in primary CABG patients obtained by using risk adjustments [Arom 2000] and multivariate analyses [Puskas 2000, Calafiore (unpublished)] in primary CABG patients.

Table 5: Determinants of perioperative mortality and morbidity in reoperative CABG

	Mortality		Stroke		Adverse Outcome	
	P	OR	P	OR	P	OR
Age	= 0.007	1.08			= 0.005	1.04
PVD	= 0.044	2.33				
CHF	= 0.007	1.91				
#Grafts	= 0.013	1.48	= 0.001	2.16	= 0.023	1.29
Previous stroke			< 0.005	9.90		
Calcified Aorta			= 0.029	6.09		
CPB					< 0.005	2.89

PVD = peripheral vascular disease, CHF = congestive heart failure, CPB = cardiopulmonary bypass

Our analysis was also aimed at identifying the determinants for perioperative CVA. Although a significantly higher rate of stroke was reported in the on-pump group, multivariable analysis did not show any correlation between CPB and perioperative CVA. When the analysis was extended to the overall number of postoperative complications (adverse outcome), CPB was the strongest independent risk factor (OR 2.9), thus confirming findings at univariate analysis. However, case assignment and individual surgeon's preferences may have had more impact on outcome than CPB, although, at multivariable analysis, no relationship was found between the different surgeons and perioperative mortality and morbidity. Moreover, because the two groups had a significantly different surgical priority, extent of CAD, and number of coronary grafts performed, we decided to introduce all three of these variables in the logistic regression model. Although the first two variables did not show any independent relationship with mortality or major morbidity, the number of grafts performed was positively related to mortality, adverse outcome, and stroke rate. This finding could justify the use of pedicled arterial grafts or venous grafts from the descending aorta in order to avoid the possible deleterious effects of ascending aorta manipulation for construction of proximal anastomoses. The effect of the number of grafts and graft/patient ratio may be different at follow-up. In this regard, some authors have documented higher rates of recurrent angina and cardiac reintervention in patients operated on off-CPB [Gundry 1998, Arom 2000]. This may be attributable to surgeons performing fewer grafts initially because of relative unfamiliarity with the newer procedure, resulting in a higher reintervention rate. More recently several authors

[Bhan 2000, Cremer 2000, Repossini 2000] have shown excellent results with MIDCAB [Cremer 2000, Repossini] and OPCAB [Bhan 2000] at short-term angiography [Cremer 2000, Repossini] and mid-term clinical follow-up [Bhan 2000, Repossini 2000]. Although our analysis lacks any clinical or angiographic follow-up, intraoperative graft patency verification via transit time flow measurement (TTFM) [D'Ancona 2000] was obtained in the majority of the off-pump patients. All grafts performed were patent, at least immediately prior to chest closure.

CONCLUSION

Our results indicate that reoperative myocardial revascularization performed without CPB may limit postoperative complications without increasing mortality rate. Although most patients can be safely treated via median sternotomy and on-CPB, revascularization of isolated "culprit" lesions may be achieved without CPB with alternative surgical approaches, using arterial conduits (RGEA, LIMA, and RIMA), and constructing proximal anastomoses on the descending thoracic aorta or epiaortic vessels. Avoidance of CPB does not seem to independently reduce perioperative mortality or stroke rate. On the other hand, an independent relationship between number of overall adverse outcomes and CPB does seem to exist. It should be noted that our findings may be biased by the retrospective, non-randomized nature of the study. Prospective randomized studies are in progress to better define the appropriate uses of off-pump reoperative CABG.

REFERENCES

1. Akhter M, Lajos T, Grosner G, et al. Reoperations with the right gastroepiploic artery without cardiopulmonary bypass. J Card Surg 12:210-14, 1997.
2. Allen KB, Matheny RG, Robison RJ, et al. Minimally invasive versus conventional reoperative coronary artery bypass. Ann Thorac Surg 64:616-22, 1997.
3. Aranki SF, Rizzo RJ, Adams DH, et al. The single cross-clamp technique: an important adjunct to myocardial and cerebral protection in coronary operations. Ann Thorac Surg 58(2):296-303, 1994.
4. Arom KV, Flavin TF, Emery RW, et al. Safety and efficacy of off-pump coronary artery bypass grafting. Ann Thorac Surg 69:704-10, 2000.
5. Ascione R, Lloyd CT, Underwood M, et al. On pump versus off pump coronary revascularization: evaluation of renal function. Ann Thorac Surg 68:493-8, 1999.
6. Ascione R, Lloyd CT, Gomes WJ, et al. Beating versus arrested heart revascularization: evaluation of myocardial function in a prospective randomized study. Eur J Cardiothorac Surg 15:685-90, 1999.
7. Ascione R, Clinton T, Underwood M, et al. Inflammatory response after coronary revascularization with and without cardiopulmonary bypass. Ann Thorac Surg 69:1198-1204, 2000.
8. Baumgartner FJ, Gheissari A, Panagiotides GP. Off-pump obtuse marginal grafting with local stabilization: thoracotomy approach in reoperations. Ann Thorac Surg 68:946-8, 1999.
9. Benetti FJ, Naselli G, Wood M, et al. Direct myocardial revascularization without extracorporeal circulation: experience in 700 patients. Chest 100:312-6, 1991.
10. Bergsland J, Karamanoukian HL, Soltoski P, et al. "Single suture" technique to help expose the heart for complete revascularization without cardiopulmonary bypass. Ann Thorac Surg 68:1428-30, 1999.
11. Bergsland J, Schmid S, Yanulevich J, et al. Coronary artery bypass grafting (CABG) without cardiopulmonary bypass (CPB): a strategy for improving results in surgical revascularization. Heart Surg Forum #1998-1593;1(2):107-10, 1998.
12. Bhan A, Choudhary SK, Mathur A, et al. Surgical myocardial revascularization without cardiopulmonary bypass. Ann Thorac Surg 69:1216-21, 2000.
13. Boonstra PW, Grandjean JG, Mariani MA. Reoperative coronary artery bypass grafting without cardiopulmonary bypass through a small thoracotomy. Ann Thorac Surg 63:405-7, 1997.
14. Buckberg GD. Antegrade/retrograde blood cardioplegia to ensure cardioplegic distribution: operative techniques and objectives. J Card Surg 4:216-38, 1989.
15. Buffolo E, Andrade JCS, Branco JNR, et al. Myocardial revascularization without extracorporeal circulation: seven year experience in 593 cases. Eur J Cardiothorac Surg 4:504-9, 1990.
16. Butler J, Rocker GM, Westaby S. Inflammatory response to cardiopulmonary bypass. Ann Thorac Surg 55:552-9, 1993.
17. Calafiore AM (unpublished data).
18. Calafiore AM, Di Giammarco GD, Teodori G, et al. Left anterior descending coronary artery grafting via a left anterior small thoracotomy without cardiopulmonary bypass. Ann Thorac Surg 61:1658-63, 1996.
19. Calhourn TR, Johnston RH, McKowen RL, et al. Retrograde coronary sinus cardioplegia in redo aorto-coronary bypass. Ann Thorac Surg 49:686-8, 1990.
20. Cohn W, Suen HC, Weintraub RM, et al. The "H" graft: an alternative approach for performing minimally invasive direct coronary artery bypass. J Thorac Cardiovasc Surg 115:148-51, 1998.
21. Cremer JT, Wittwer T, Boning A, et al. Minimally invasive coronary artery revascularization on the beating heart. Ann Thorac Surg 69:1787-91, 2000.
22. D'Ancona G, Karamanoukian H, Ricci M, et al. Graft revision after transit time flow measurement in off-pump coronary artery bypass grafting. Eur J Cardiothorac Surg 17:287-93, 2000.
23. Diegeler A, Hirsch R, Schneider F, et al. Neuromonitoring and neurocognitive outcome in off-pump versus conventional coronary bypass operation. Ann Thorac Surg 69:1162-6, 2000.
24. Edmunds LH Jr. Inflammatory response to cardiopulmonary bypass. Ann Thorac Surg 66:S12-6, 1998.
25. Fanning WJ, Kakos GS, Williams TE. Reoperative coronary artery bypass grafting without cardiopulmonary bypass. Ann Thorac Surg 55:486-9, 1993.
26. Fonger JD, Doty JR, Sussman MS, et al. Lateral MIDCAB

grafting via limited posterior thoracotomy. Eur J Cardiothorac Surg 12 399-405, 1997.
27. Grandjean JG, Mariani MA, Ebels T. Coronary reoperation via small laparotomy using right gastroepiploic artery without cardiopulmonary bypass. Ann Thorac Surg 61:1853-5, 1996.
28. Grosner G, Lajos TZ, Schimert G, et al. Left thoracotomy reoperation for coronary artery disease. J Card Surg 5:304-8, 1990.
29. Gundry SR, Romano MA, Shattuck OH, et al. Seven-year follow-up of coronary artery bypasses performed with and without cardiopulmonary bypass. J Thorac Cardiovasc Surg 115:1273-8, 1998.
30. Hannan EL, Kilburn H, O'Donnel JF, et al. Adult open heart surgery in New York State. An analysis of risk factors and hospital mortality rates. JAMA 264:2768-74, 1990.
31. He GW, Acuff TE, Ryan WH, et al. Determinants of operative mortality in reoperative CABG. J Thorac Cardiovasc Surg 110:971-8, 1995.
32. Kshettry V, Flavin T, Emery R, et al. Does multivessel off pump coronary artery bypass reduce postoperative morbidity? Ann Thorac Surg 69:1725-31, 2000.
33. Loop FD, Lytle BW, Cosgrove DM, et al. Reoperation for coronary atherosclerosis. Changing practice in 2509 consecutive patients. Ann Surg Sept. 212:378-86, 1990.
34. Lytle BW, Loop FD, Cosgrove DM, et al. Fifteen hundred coronary reoperations: results and determinants of early and late survival. J Thorac Cardiovasc Surg 93:847-59, 1987.
35. Miyaji K, Wolf RK, Flege JB. Minimally invasive direct coronary artery bypass for redo patients. Ann Thorac Surg 67:1677-81, 1999.
36. Moshkovitz Y, Lusky A, Mohr R. Coronary artery bypass without cardiopulmonary bypass: analysis of short-term and mid-term outcome in 220 patients. J Thorac Cardiovasc Surg 110:979-87, 1995.
37. Ohata T, Sawa Y, Kadoba K, et al. Effect of cardiopulmonary bypass under tepid temperature on the inflammatory reactions. Ann Thorac Surg 64:124-8, 1997.
38. Pfister A, Zaki S, Garcia JM, et al. Coronary artery bypass without cardiopulmonary bypass. Ann Thorac Surg 54:1085, 1992.
39. Puskas JD, Wright CE, Ronson RS, et al. Clinical outcomes and angiographic patency in 165 consecutive off-pump coronary bypass patients. Presented at the 36th STS meeting, Feb. 2000, Ft. Lauderdale, FL.
40. Repossini A, Moriggia S, Cianci V, et al. The LAST operation is safe and effective: MIDCABG clinical and angiographic evaluation. Ann Thorac Surg 70:74-8, 2000.
41. Ricci M., Karamanoukian H, Jajkowski MR, et al. The innominate artery as an inflow site in coronary reoperations without cardiopulmonary bypass. Ann Thorac Surg 69(5):1606-8, 2000.
42. Salerno TA. Single cross-clamping period for the proximal and distal anastomoses in coronary surgery: an alternative to conventional techniques. Ann Thorac Surg 33:518-20, 1982.
43. Savage EB, Cohn LH. "No-Touch" dissection, antegrade-retrograde blood cardioplegia, and single aortic cross-clamp significantly reduce operative mortality of reoperative CABG. Circulation 90(part 2):II-140–II-143, 1994.
44. Stamou S, Pfister A, Dangas G, et al. Beating heart versus conventional single-vessel reoperative coronary artery bypass. Ann Thorac Surg 69:1383-7, 2000.

REVIEW AND COMMENTARY

1. Editorial Board Member GX21 writes:

(1) The Results section refers to four estimates of mortality: (1) actual, (2) risk-adjusted, (3) observed, (4) expected. I assume that (1) is simply the number of deaths divided by the number of patients. Is (3) the same thing? What is (2), i.e., how was the risk-adjustment done? If it was normalized for all CABG mortality for the state of New York, that is not a worthwhile estimate, since these are only re-do patients. Also, it is not apparent how the O/E ratio was derived.

(2) The p-value for Stroke in Table 4 is .026 not < .005 by chi-square test.

(3) In the second sentence of the second paragraph of the Results section, why not just give overall complications as a percentage, rather than as percentage-free, for consistency with the presentation of other individual complications?

Response by Saira Hasnain, Department of Biostatistics, University of Buffalo, Buffalo, NY

"Actual mortality rate" (or observed mortality, or crude mortality) was defined, according to the New York State database indications, as deaths occurring within 30 days from the operation divided by the total number of operations.

In regard to "expected mortality" and "risk adjusted mortality" rates, the statistical analysis done following the directions of NYS database Form DOH-225a (1-98) consists of determining which of the risk factors collected are significantly related to in-hospital death for CABG surgery and determining how to weight the significant risk factors to predict the chance each patient will have of dying in the hospital, given his or her specific characteristics. The statistical methods used to predict mortality on the basis of the significant risk factors are tested to determine if they are sufficiently accurate in predicting mortality for patients who are extremely ill prior to surgery as well as for patients who are relatively healthy. These tests have confirmed the models and are reasonably accurate in predicting how patients, of all different risk levels, will fare when undergoing CABG. The mortality rate for each group of patients is predicted by summing the predicted possibilities of death for each patient and dividing by the number of patients. The resulting rate is an estimate of what the groups mortality rate would have been if the groups' performances were identical to the state performance. The percentage is called the "predicted" or "expected" mortality. The "risk adjusted mortality rate" represents the best estimate, based on the associated statistical model, of what the groups mortality rate would have been if the groups had been similar to the statewide mix. Risk adjusted mortality rates were calculated dividing the actual mortality by the expected mortality, and multiplying this figure by the overall state mortality rate (2.52% for 1995 in NYS) to balance it out.

The O/E ratio (observed/expected mortality ratio) is derived by dividing the observed (or actual, or crude) mortality rate by the expected mortality rate (as above defined).

The "freedom from complications rate" is one of the categories of the NYS database Form DOH-225a (1-98). For this reason, we preferred to consider this definition instead of the "overall complication" rate one.

2. Editorial Board Member EK34 writes:

The conclusion in both the body and abstract about morbidity being decreased is not supported. No risk-adjusted morbidity data were given. It is not surprising that sicker patients (as demonstrated by the double predicted risk) would have more complications. Therefore, no conclusion can be drawn.

The operative mortality of an O/E ratio of 2.7 is extremely high. The populations at risk needing one rather than three grafts are very different. Since there were one-half the number of grafts in the off-pump group, a metric analysis of the consequences of incomplete revascularization would be most appropriate.

Authors' Response by Giuseppe D'Ancona, MD:

The two populations in analysis are different because the study is not randomized. A logistic regression analysis was conducted to define the variables that were related to mortality and adverse outcome independently from the other preoperative and perioperative variables (including all the preoperative risk factors, extension of CAD, and number of performed grafts). Use of CPB did not seem to be independently related to perioperative mortality, but the relationship with total number of adverse outcomes was clear (OR 2.89). These are the results of our logistic regression analysis and for this reason we may conclude that avoidance of CPB does reduce the number of adverse outcomes independently of the other pre- and perioperative variables. This conclusion is of course limited to our personal experience in this selected group of reoperative CABGs.

The relationship between the number of performed grafts, mortality, and adverse outcome was also investigated. Surprisingly, the number of grafts was independently related to mortality (OR 1.48), stroke (OR 2.16), and adverse outcome (OR 1.29). This is probably due to the fact that the higher the number of performed grafts, the higher the chance of aortic and heart manipulation that may cause thromboembolic events.

The long-term effects of incomplete myocardial revascularization have not been analyzed in this study. A long-term follow-up of our total experience with OPCABG since 1996 has been completed and its very encouraging results will be presented in the near future.

3. Editorial Board Member TY12 writes:

The authors should separate MIDCAB procedures from OPCABs, as there is a higher graft/patient ratio in the OPCAB group.

Authors' Response by Giuseppe D'Ancona, MD:

This is true. It is also true that a large number of patients that underwent MIDCAB had revascularization that was limited to "culprit coronary lesions." In this sense the number-of-grafts/number-of-diseased-coronaries ratio is always higher in the on-pump group.

4. Editorial Board Member SO155 writes:

The authors need to review the statistical analysis because the number of grafts is different.

Authors' Response by Giuseppe D'Ancona, MD:

There is no statistical difference in the graft/patient ratio. The statistical analysis has been repeated and the data are correct. There is of course a trend towards a higher number of grafts in the on-CPB group. As mentioned in the paper, there was, at least in the beginning of our experience with OPCABG, a tendency to revascularize only "culprit" coronary lesions.

5. Editorial Board Member RF155 writes:

The article does not stratify results of the off-pump group into limited access versus median sternotomy approaches. Also, the MIDCAB references for the limited access experience are incomplete.

Authors' Response by Giuseppe D'Ancona, MD:

We have performed the analysis separating the off-CPB group into median sternotomy and limited access groups. No differences were noticed in the analysis.

6. Editorial Board Member JZ39 writes:

The article really compares how two different groups of patients are selected for complementary therapies and does not address the differences in the outcomes of two techniques applied to similar patients but, rather, how the authors apply different techniques to their patient mix.

Authors' Response by Giuseppe D'Ancona, MD:

This study summarizes one of the largest experiences in reoperative off-CPB CABG. The referral pattern for off-CPB and conventional CABG is different and, for this reason, the two populations in analysis differ in many ways. Surgeons' and cardiologists' attitudes towards off-CPB and conventional CABG are different, and prospective, randomized studies are impossible to perform in most institutions (including ours). We tried to separate the off-CPB group into smaller subgroups (median sternotomy and limited access) to reduce the "patient mix." No differences were noted. For this reason we decided to compare the overall population of off-CPB redo CABG to the conventional CABG group. To exclude the possible bias of the non-randomization, we performed a multivariable analysis trying to identify the determinants of mortality and adverse outcomes. The differences in the outcomes of the two techniques are clearly addressed in the logistic regression analysis.