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Outcomes of Off-Pump versus On-Pump Coronary Artery Bypass Surgery in End-Stage Renal Disease Patients with a History of Myocardial Infarction

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ABSTRACT

Background. Patients with end-stage renal disease (ESRD) and myocardial infarction (MI) have poor survival. Coronary artery bypass grafting (CABG) in select patients is an effective treatment strategy; however, whether operative technique influences hospital outcome is not defined.

Methods. Between 1995 and 2000, 342 patients had ESRD (creatinine >2.0 mg/dL or dialysis) and a history of MI at the time of CABG. There were 67 patients that had off-pump coronary artery bypass (OPCAB) (OFF) and 275 that had CABG (ON). The OFF group was compared to the ON group for clinical, operative, outcome data, and influence of acuity of MI.

Results. The OFF group was older ($P = .09$), but hypertension was more common in the ON group (82% versus 69%, $P = .02$). The frequency of diabetes, congestive heart failure, peripheral vascular disease, and dyslipidemia were common, but not different between groups. For the OFF versus ON group, creatinine serum level was 3.6 ± 2.6 versus 3.5 ± 3.1 ($P = 0.17$), and history of an acute MI was 39% versus 33% ($P = 0.78$). The OFF versus ON group had fewer total grafts (2.5 ± 1 versus 3.8 ± 1, $P < .001$). The OFF group had fewer strokes ($P = .08$), shorter intensive care unit stay (2.4 versus 3.8 days), and shorter hospitalization (8.4 versus 11.7 days), yet mortality was similar (7% versus 9%, $P = .79$). After acute MI, OFF patients had significantly more postoperative supraventricular tachycardia than ON (69% versus 19%, $P < .001$).

Conclusions. Patients with ESRD and an MI have acceptable hospital outcomes regardless of operative strategy. OPCAB or CABG may provide an advantage in certain patients, yet it is the presence of an acute MI that is a predictor of postoperative events.

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INTRODUCTION

Cardiovascular disease is the most common cause of death in patients with end-stage renal disease (ESRD). In this patient group, after a myocardial infarction (MI), mortality rises to 60% within the year and 72% are dead within 2 years [Herzog 1999; Collins 2001]. Indeed, individuals with chronic kidney disease are more likely to die of coronary artery disease than to develop kidney failure [Sarnak 2003]. Why are death rates so high? The answer appears to be a combination of disease variables and the lack of aggressive intervention by physicians with respect to coronary artery disease. The United States Renal Data System cardiovascular symposium at the American Society of Nephrology 2000 annual meeting presented data on revascularization rates in the adult dialysis population. Their data demonstrated an increased survival in the first, second, and third years postrevascularization but they found that, at the same time, few patients are being evaluated for cardiac surgery [Collins 2001]. Many physicians are reluctant to refer ESRD patients for coronary revascularization for fear of complications and poor outcomes.

The fear of complications is a reasonable one. Patients with mild chronic kidney disease experience a doubling of mortality compared to patients without chronic kidney disease after cardiac revascularization [Szczech 2002]. Operative mortality is even higher in ESRD patients. In the last 10 years, studies have reported an aggregate mortality rate between 8.9% and 12.5% [Vaitkus 2000]. This includes a higher rate of in-hospital mortality, mediastinitis, and postoperative cerebrovascular events [Liu 2000]. However, data do exist supporting intervention. Herzog reported that previous coronary revascularization was associated with a 13% decrease in risk of overall mortality and a 10% decrease in cardiac mortality [Herzog 1998]. The patient who undergoes coronary artery bypass grafting (CABG) in the setting of a MI is also at increased risk of perioperative morbidity and mortality. The patient with renal dysfunction who undergoes CABG in the setting of a MI is, understandably, at extremely high risk [Herzog 1998; Szczech 2002; Sarnak 2003]. The role of CABG in renal dysfunction patients in the setting of MI is still being defined. The purpose of our study was to address whether operative technique influences outcome in these high risk patients.

Table 1. Baseline and Intraoperative Characteristics of the Off-Pump versus On-Pump Patients*

	OPCAB Group (n = 67)	On-Pump Group (n = 275)	*P*
Age 61-99, n (%)	54 (81)	188 (68)	.09
Acute MI, n (%)	26 (39)	93 (34)	.78
Creatinine, mg/dL†	3.6 ± 2.6	3.5 ± 3.1	.17
Diabetes, n (%)	37 (55)	137 (50)	.51
PVD, n (%)	15 (22)	80 (29)	.34
COPD, n (%)	6 (9)	36 (13)	.47
CHF, n (%)	20 (30)	68 (25)	.48
HTN, n (%)	46 (69)	226 (82)	.02
Smokers, n (%)	24 (36)	50 (18)	.003
Hyperlipidemia, n (%)	36 (54)	143 (52)	.91
Grafts, n†	2.5 ± 1.0	3.8 ± 1.0	<.001
Timing of case, n (%)			
Elective	35 (52)	65 (24)	<.001
Urgent	32 (48)	189 (68)	.002
Emergent	0	21 (8)	.04

*OPCAB indicates off-pump coronary artery bypass; MI, myocardial infarction; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; HTN, hypertension.

†Mean ± standard deviation.

MATERIALS AND METHODS

Between 1995 and 2000, 10,291 consecutive patients underwent isolated CABG at the Washington Hospital Center (WHC). Of these, 342 patients (3.3%) had chronic renal disease or ESRD defined in accordance with The Society of Thoracic Surgeons as serum creatinine (Cr) >2.0 mg/dL or dialysis dependence. There were 119 patients (35%) who had an acute MI (AMI) (<7 days), and 223 patients (65%) who had a remote MI (RMI) (>7 days) at the time of CABG.

All data were prospectively collected and captured through the WHC Cardiac Surgery database. Patient inclusion was nonrandomized, and analysis was retrospective. Patient inclusion was based on referral for CABG and designations as an operable candidate by the operating surgeon. Comparison was made between the off-pump group and the cardiopulmonary bypass group. Analysis was performed on group demographics, clinical variables, operative data, and hospital outcomes.

Operative technique was uniform for all surgeons, although the choice for off-pump (OPCAB) was made by on the individual surgeons. All participating surgeons were experienced in OPCAB techniques. For patients undergoing conventional CABG, mean arterial pressure was maintained >70 mmHG, the temperature was allowed to drift, but not below 32°C, and a hemoconcentrator was used in the cardiopulmonary bypass circuit for dialysis patients. For the OPCAB technique, a vessel stabilizer, usually of the suction type, was used, and vessel loops (not circumferential) rather than occluders controlled coronary blood flow. An apical suction device was used as a heart positioner. Postoperatively, the renal service was an active participant in the management of all patients.

The statistical analysis was performed using SigmaStat statistical software (Jandel Scientific, San Rafael, CA, USA). The statistical tests applied were the Student *t* test and the Mann-Whitney rank sum test when the equal variance test was violated. Chi-square test was used for categorical values. $P < .05$ was considered statistically significant.

The WHC Cardiac Surgery Research Committee under the Director of Cardiac Surgery and the Executive Director of Washington Heart approved this study. No author has any financial disclosures.

RESULTS

The baseline and intraoperative characteristics of the off-pump and on-pump group are compared in Table 1. The majority of patients in both groups were older than 61 years, with the off-pump group tending to be older. Cr was similar between the 2 groups, and there were similar incidences of diabetes, peripheral vascular disease, chronic obstructive pulmonary disease, congestive heart failure, and hyperlipidemia. There was a statistically significant higher number of smokers in the off-pump group and a statistically higher occurrence of hypertension in the on-pump group.

The on-pump group had a significantly greater number of bypass grafts (3.8 ± 1.0 versus 2.5 ± 1.0, $P < .001$). Finally, the timing of cases was significantly different between the 2 groups, with more of the off-pump cases being elective (52% versus 24%, $P < .001$) and more of the on-pump cases being performed urgently or emergently.

Table 2 contains the postoperative data and the adverse events of the off-pump group versus on-pump group. There was no significant difference in any of the recorded data. Mortality rates were 7% in the OPCAB group and 9% in the on-pump group ($P = .79$). Average hospital stays for the

Table 2. Postoperative Data and Adverse Events of the Off-Pump versus On-Pump Patients*

Variable	OPCAB Group (n = 67)	On-Pump Group (n = 275)	*P*
Death, n (%)	5 (7)	26 (9)	.79
Reopening for hemorrhage, n (%)	4 (6)	11 (4)	.71
Cardiac arrest, n (%)	1 (1)	14 (5)	.34
Myocardial infarction, n (%)	0	2 (1)	.85
Tamponade, n (%)	2 (3)	2 (1)	.36
Atrial fibrillation, n (%)	24 (36)	96 (35)	1.00
Supraventricular tachycardia, n (%)	26 (39)	81 (29)	.18
Pulmonary embolus	0	1 (<1)	.44
Prolonged ventilatory support, n (%)	5 (7)	31 (11)	.49
Requiring tracheostomy, n (%)	1 (1)	11 (4)	.53
Mental status change, n (%)	10 (15)	41 (15)	.85
Postoperative stroke, n (%)	0	17	.08
Average hospital stay, d	8.4	11.7	—
Median ICU stay, d	2.4	3.8	—

*OPCAB indicates off-pump coronary artery bypass; ICU, intensive care unit.

Table 3. Baseline and Intraoperative Characteristics of the RMI versus AMI OPCAB Patients*

	RMI OPCAB Group (n = 41)	AMI OPCAB Group (n = 26)	P
Age 61-99, n (%)	33 (80)	21 (81)	.94
Creatinine, mg/dL†	3.7 ± 2.7	3.3 ± 2.5	.59
Diabetes, n (%)	25 (61)	12 (46)	.35
PVD, n (%)	9 (22)	6 (23)	.85
COPD, n (%)	4 (10)	2 (8)	1.00
CHF, n (%)	10 (24)	10 (38)	.34
HTN, n (%)	32 (78)	14 (54)	.07
Smokers, n (%)	13 (32)	11 (42)	.54
Hyperlipidemia, n (%)	23 (56)	13 (50)	.81
Grafts, n†	2.4 ± 1.1	2.6 ± 0.9	.28
Timing of case, n (%)			
Elective	21 (51)	14 (54)	.97
Urgent	20 (49)	12 (46)	.97
Emergent	0	0	N/A

*RMI indicates remote myocardial infarction (>7 days); AMI, acute myocardial infarction (<7 days); OPCAB, off-pump coronary artery bypass; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; HTN, hypertension.

†Mean ± standard deviation.

OPCAB group were 8.4 days with 2.4 in the intensive care unit (ICU) as compared to 11.7 days in the on-pump group with 3.8 of those days being spent in the ICU. There was a trend toward a higher postoperative stroke rate in the on-pump group (6% versus 0%, *P* = .08).

The RMI group is compared to the AMI group in Table 3. Both groups are highly similar in age, Cr level, and preoperative medical conditions. There was a similar number of grafts between the 2 groups, and the timing of the cases was also similar.

Table 4. Postoperative Data and Adverse Events of the RMI versus AMI OPCAB Patients*

Variable	RMI OPCAB Group (n = 41)	AMI OPCAB Group (n = 26)	P
Death, n (%)	2 (5)	3 (11)	.37
Reopening for hemorrhage, n (%)	3 (7)	1 (4)	.82
Cardiac arrest, n (%)	0	1 (4)	.39
Myocardial infarction, n (%)	0	0	N/A
Tamponade, n (%)	1 (2)	1 (4)	1.00
Atrial fibrillation, n (%)	8 (20)	16 (61)	.001
Supraventricular tachycardia, n (%)	8 (20)	18 (69)	<.001
Pulmonary embolus	0	0	N/A
Prolonged ventilatory support, n (%)	1 (2)	4 (15)	.07
Requiring tracheostomy, n (%)	0	1 (4)	.39
Mental status change, n (%)	5 (12)	5 (19)	.49
Postoperative stroke, n (%)	0	0	N/A

*RMI indicates remote myocardial infarction (>7 days); AMI, acute myocardial infarction (<7 days); OPCAB, off-pump coronary artery bypass.

Table 5. Baseline and Intraoperative Characteristics of the AMI Patients*

Characteristic	Off-Pump Group (n = 26)	On-Pump Group (n = 93)	P
Age 61-99, n (%)	21 (81)	65 (70)	.49
Creatinine, mg/dL†	3.3 ± 2.5	3.1 ± 2.6	.34
Diabetes, n (%)	12 (46)	38 (41)	.80
PVD, n (%)	6 (23)	20 (21)	.92
COPD, n (%)	2 (8)	17 (18)	.32
CHF, n (%)	10 (38)	16(17)	.04
HTN, n (%)	14 (54)	76 (82)	.008
Smokers, n (%)	11 (42)	19 (20)	.04
Hyperlipidemia, n (%)	13 (50)	49 (53)	.98
Grafts, n†	2.6 ± 0.9	3.9 ± 0.9	<.001
Timing of case, n (%)			
Elective	14 (54)	26 (28)	.03
Urgent	12 (46)	53 (57)	.45
Emergent	0	14 (15)	.08

*AMI indicates acute myocardial infarction (<7 days); PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; HTN, hypertension.

†Mean ± standard deviation.

Postoperative data comparing the acute and remote MI groups are contained in Table 4. There was little difference in adverse events between the acute and remote MI groups. However, in the AMI group there was a significantly higher incidence of postoperative supraventricular tachycardia (69% versus 20%, *P* < .001) and atrial fibrillation (61% versus 20%, *P* = .001). There was also a trend toward a longer ventilatory support time in the AMI group.

Table 5 contains data on the baseline and intraoperative characteristics of the AMI group patients undergoing either traditional or off-pump CABG. There was no statistical difference between the 2 groups in age, Cr level, presence of diabetes, peripheral vascular disease, or chronic obstructive pulmonary disease. The off-pump group had a significantly higher percentage of smokers and patients with congestive heart failure, but the on-pump group included a greater number of smokers. The off-pump group included more elective cases, while the emergent cases tended to be done on-pump.

The outcome data of renal dysfunction patients with AMI undergoing either off-pump or on-pump CABG are contained in Table 6. There was no significant difference in outcomes between the 2 groups. A 10% death rate was seen in the on-pump group and 11% in the off-pump group; however, this was not statistically significant. There was a significantly higher number of patients who experienced supraventricular tachycardia in the off-pump group as compared to the on-pump group (69% versus 19%, *P* < 0.001). All other postoperative outcomes were similar.

Table 7 contains the preoperative and intraoperative data of the patients with renal dysfunction and RMI who underwent off-pump or on-pump CABG. The groups again were very similar, with the off-pump group having

Table 6. Postoperative Data and Adverse Events of the AMI Patients*

Variable	Off-Pump Group (n = 26)	On-Pump Group (n = 93)	*P*
Death, n (%)	3 (11)	9 (10)	.93
Reopening for hemorrhage, n (%)	1 (4)	2 (2)	.83
Cardiac arrest, n (%)	1 (4)	3 (3)	.65
Myocardial infarction, n (%)	0	1 (1)	.49
Tamponade, n (%)	1 (4)	1 (1)	.91
Atrial fibrillation, n (%)	16 (61)	40 (71)	.15
Supraventricular tachycardia, n (%)	18 (69)	18 (19)	<.001
Pulmonary embolus, n	0	1 (1)	.49
Prolonged ventilatory support, n (%)	4 (15)	9 (10)	.64
Requiring tracheostomy, n (%)	1 (4)	3 (3)	.65
Mental status change, n (%)	5 (19)	10 (11)	.41
Postoperative stroke, n (%)	0	6 (6)	.41

*AMI indicates acute myocardial infarction (<7 days).

more smokers. Similar to the AMI group, those undergoing on-pump cases were statistically more likely to have an urgent or emergent timing. More off-pump bypasses were elective when compared to the on-pump group (51% versus 21%, $P < .001$).

Postoperative outcomes were similar in both the off-pump and on-pump groups, with similar death rates (5% to 9%). Patients undergoing off-pump surgery were more likely to have supraventricular tachycardia (35% versus 20%, $P = .09$) (Table 8).

Table 7. Baseline and Intraoperative Characteristics of the RMI Patients*

Characteristic	Off-Pump Group (n = 41)	On-Pump Group (n = 182)	*P*
Age 61-99, n (%)	33 (80)	123 (68)	.19
Creatinine, mg/dL†	3.7 ± 2.7	3.7 ± 3.3	.26
Diabetes, n (%)	25 (61)	99 (54)	.55
PVD, n (%)	9 (22)	60 (33)	.23
COPD, n (%)	4 (10)	19 (10)	.88
CHF, n (%)	10 (24)	52(29)	.72
HTN, n (%)	32 (78)	150 (82)	.67
Smokers, n (%)	13 (32)	31 (17)	.06
Hyperlipidemia, n (%)	23 (56)	94 (52)	.73
Grafts, n†	2.4 ± 1.1	3.7 ± 1.0	<.001
Timing of case, n (%)			
Elective	21 (51)	39 (21)	<.001
Urgent	20 (49)	136 (75)	.002
Emergent	0	7 (4)	.44

*RMI indicates remote myocardial infarction (>7 days); PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; HTN, hypertension.

†Mean ± standard deviation.

Table 8. Postoperative Data and Adverse Events of the RMI Patients*

Variable	Off-Pump Group (n = 41)	On-Pump Group (n = 182)	*P*
Death, n (%)	2 (5)	17 (9)	.54
Reopening for hemorrhage, n (%)	3 (7)	9 (5)	.82
Cardiac arrest, n (%)	0	11 (6)	.22
Myocardial infarction, n (%)	0	1 (1)	.41
Tamponade, n (%)	1 (2)	1 (1)	.81
Atrial fibrillation, n (%)	8 (20)	56 (31)	.21
Supraventricular tachycardia, n (%)	8 (20)	63 (35)	.09
Pulmonary embolus, n	0	0	N/A
Prolonged ventilatory support, n (%)	1 (2)	22 (12)	.12
Requiring tracheostomy, n (%)	0	8 (4)	.37
Mental status change, n (%)	5 (12)	31 (17)	.60
Postoperative stroke, n (%)	0	11 (6)	.22

*RMI indicates remote myocardial infarction (>7 days).

DISCUSSION

Morbidity and mortality are increased in renal dysfunction patients for various reasons. There is an increased risk of infections, sepsis, volume, and electrolyte disturbances [Owen 1994]. They have an increased prevalence of atherosclerotic risk factors and an overall increased risk profile including advanced age, congestive heart failure, hypertension, peripheral vascular disease, and chronic obstructive pulmonary disease [Szczech 2002]. Because of the increased morbidity and mortality, physicians have been reticent to refer these patients for CABG surgery.

The most effective treatment for patients with renal disease and ischemic heart disease is not yet well defined. Patients with chronic renal disease have been shown to fare poorly with medical therapy or percutaneous therapy [Herzog 1999, 2002; Szczech 2002]. Today, more patients with ESRD and coronary artery disease are being referred for coronary bypass based on data suggesting better long-term survival over medical or percutaneous treatment modalities [Owen 1994; Rao 1997; Liu 2000; Herzog 2002]. Although the benefit of surgery is not immediately appreciated because of the high incidence of periprocedural mortality, studies have demonstrated the long-term benefits of surgical repair, citing decreased incidence of angina, improved survival, and better overall functional status [Owen 1994; Rao 1997]. For these high-risk patients, coronary bypass surgery may be the only viable therapy.

Our group recently reported data on outcomes of bypass surgery in the ESRD patient with MI. We found that these patients had acceptable perioperative morbidity and mortality rates. Hospital mortality was no different between the acute and remote MI groups (10% versus 8.5%, $P = .88$). We concluded that these outcomes suggest that CABG is an acceptable therapeutic option in this high-risk patient group [Trachiotis 2003]. Our data, however, did not discriminate between off-pump and conventional CABG.

The benefits of off-pump coronary artery surgery in non-dialysis patients have been reported by several groups, including ours. Postoperative events, hospital and ICU stays, ventilator times, and stroke rates were all decreased in the off-pump groups [Ascione 1999; Trachiotis 2001; Loef 2002; Moore 2005]. We theorized that OPCAB outcomes in the high-risk renal failure patient with a history of MI might also be improved. Our data, however, does not support this. There was an indication of decreased postoperative strokes in the off-pump group (0% versus 17% in the on-pump group, $P = .08$), but the remainder of our measured outcomes demonstrated no significant differences. This finding suggests that either on-pump or off-pump approaches are acceptable in this patient population with death rates of 7% in the OPCAB group and 9% in the conventional group.

When we further divided our data into acute versus remote MI, we found specifically that the AMI group had significantly increased rates of atrial fibrillation (61% versus 20%, $P = .001$) and supraventricular tachycardia (69% versus 20%, $P < .001$) in the postoperative period. Most likely, this reflects an increase in myocardial irritability secondary to the infarction. Whether this increase in postoperative arrythmias has any significant long-term implications is unknown. Interestingly, when further subdivided, we found that the patients at greatest risk for postoperative arrythmias, namely supraventricular tachycardias, were those who had suffered an AMI and underwent off-pump bypass (69% AMI off-pump versus 19% AMI on-pump, $P < .001$). In those patients with a history of RMI, there was an indication of increased postoperative supraventricular tachycardia as well (35% RMI off-pump versus 20% RMI on-pump, $P = .009$). In most reports, the incidence of atrial fibrillation for OPCAB is the same, or perhaps less, than conventional bypass in elective, nonemergent conditions. In our report, although OPCAB groups tended to have a higher incidence of supraventricular tachycardia, the influence of an AMI (<7 days prior to OPCAB) may be more of a factor than operative technique [Trachiotis 2001, 2003; Moore 2005]. One explanation is that, for the AMI group, there may have been less time to optimize fluid, electrolyte, or acid-base imbalance for this subset of renal failure patients, making the myocardium in this group more sensitive to intraoperative variables, such as cardiac positioning or pharmacologic agents. Thus, for these patients, perhaps careful attention to these factors and aggressive prophylaxis for atrial fibrillation should be considered.

We conclude that patients with ESRD and an MI have acceptable hospital outcomes regardless of operative strategy. OPCAB or on-pump CABG may provide an advantage in certain patients, yet it is the presence of an AMI that is a predictor of postoperative events, and those patients are more likely to experience arrhythmias when the surgery is done off-pump.

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