On-pump versus off-pump surgical revascularization in patients with acute coronary syndromes: Analysis from the Acute Catheterization and Urgent Intervention Triage Strategy trial

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Objective: Early invasive strategy, defined as early coronary angiography and subsequent revascularization, when appropriate, is recommended by current guidelines for the management of patients with moderate- to high-risk acute coronary syndromes. We sought to compare the outcomes of patients with acute coronary syndromes undergoing surgical revascularization with an on-pump versus off-pump approach.

Methods: Among a total of 13,819 patients with moderate- to high-risk acute coronary syndromes enrolled in the Acute Catheterization and Urgent Intervention Triage Strategy trial, 1375 patients were triaged to isolated coronary artery bypass grafting. One thousand one hundred fifty-four patients underwent operations with cardiopulmonary bypass (the coronary artery bypass grafting group), and 221 patients underwent off-pump coronary artery bypass grafting (the off-pump coronary artery bypass grafting group). Propensity score matching (1:3) was applied to adjust for differences in baseline clinical and angiographic characteristics, yielding a total of 880 matched patients with acute coronary syndromes (220 managed with off-pump coronary artery bypass grafting and 660 managed with coronary artery bypass grafting).

Results: At 30 days, patients undergoing off-pump coronary artery bypass grafting had fewer events of bleeding (43.7% vs 56.3%, $P = .0005$) and myocardial infarction (7.3% vs 12.1%, $P = .055$) but higher rates of reintervention (3.7% vs 1.2%, $P = .02$). At 1 year, there was no difference between groups in death, total myocardial infarctions, reinterventions, strokes, or major adverse cardiac events, but there was a lower rate of non-Q-wave myocardial infarctions in the off-pump coronary artery bypass grafting group (4.6% vs 9.2%, $P = .03$).

Conclusions: In this large-scale study evaluating the outcomes of patients with acute coronary syndromes, off-pump coronary artery bypass grafting was associated with lower rates of bleeding and non-Q-wave myocardial infarction but more reinterventions early after the procedure. At 1 year, there was no major outcome difference between the 2 surgical strategies. (*J Thorac Cardiovasc Surg* 2011;142:e33-9)

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Early invasive strategy, defined as early coronary angiography with subsequent revascularization, when appropriate, results in higher rates of event-free survival than conservative care for patients presenting with moderate- or high-risk acute cor-

onary syndromes (ACSs)¹ and is the recommended approach of the American Heart Association, the American College of Cardiology, and the European Society of Cardiology.^{2,3} The traditional surgical approach of cooling the patient by postponing the surgical procedure in high-risk ACS scenarios to allow stabilization before the operation has been challenged by recent reports validating the positive role of coronary artery bypass grafting (CABG) in patients with ACSs.⁴⁻⁶

Although admission to hospitals with an ACS (ie, unstable angina and non-ST-segment elevation myocardial infarction [MI]) is a common and highly frequent occurrence, there are limited data illuminating the superior surgical strategy for these high-risk patients. Of interest are recent reports claiming that off-pump coronary artery bypass grafting (OPCAB) might reduce ischemic injury to the myocardium⁷⁻¹¹ and suggesting some early benefit for the OPCAB technique after EuroSCORE stratification of patients presenting with active ischemia and unstable angina.¹²

In this report we conducted a subgroup analysis for the outcome of patients with coronary disease who presented with moderate- to high-risk ACSs enrolled in the large-scale

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Abbreviations and Acronyms

ACS	= acute coronary syndrome
ACUITY	= Acute Catheterization and Urgent Intervention Triage Strategy
CABG	= coronary artery bypass grafting
CI	= confidence interval
CPK	= creatine phosphokinase
MACE	= major adverse cardiac event
MB	= myocardial band
MI	= myocardial infarction
OPCAB	= off-pump coronary artery bypass grafting
OR	= odds ratio
ULN	= upper limit of normal

contemporary Acute Catheterization and Urgent Intervention Triage Strategy (ACUITY) trial with subsequent revascularization by means of either CABG or OPCAB.

MATERIALS AND METHODS

The ACUITY trial was a prospective, open-label, randomized, multicenter trial that compared 3 different antithrombotic regimens for patients presenting with moderate- or high-risk ACSs between August 2003 and December 2005 and who were treated with an early invasive strategy. The study design and protocol, as well as its principal results, have been described previously in detail.¹³ In brief, 13,819 patients presenting with non-ST-segment elevation ACSs were randomized to receive unfractionated heparin or enoxaparin with a glycoprotein IIb/IIIa inhibitor, bivalirudin plus a glycoprotein IIb/IIIa inhibitor, or bivalirudin alone. Per protocol, angiographic analysis was intended in all patients within 72 hours of randomization, with subsequent triage to percutaneous coronary intervention, CABG surgery, or medical management.

Inclusion criteria for entering the study were age of 18 years or greater with symptoms of unstable angina lasting 10 minutes or more within 24 hours, with 1 or more of the following criteria: new ST-segment depression or transient elevation of 1 mm or greater; increased troponin I, troponin T, or creatine kinase-myocardial band (MB) levels; known coronary artery disease; or all 4 other Thrombolysis in Myocardial Infarction risk criteria.^{14,15}

Exclusion criteria included acute ST-segment elevation MI or shock, bleeding diathesis or major bleeding within 2 weeks, thrombocytopenia, creatinine clearance of 30 mL/min or less, or recent administration of abiximab, warfarin, fondaparinux, fibrinolytic agents, bivalirudin, or more than 1 dose of low-molecular-weight heparin. The study was approved by institutional review boards or ethics committees at each center, and all patients provided written informed consent.

All patients undergoing CABG received unfractionated heparin as the anticoagulant, with dosing per standard institutional practice. For patients initially randomized to bivalirudin or enoxaparin, the drug was discontinued for at least 1 or 8 hours (if possible) before surgical intervention (for bivalirudin and enoxaparin, respectively). Finally, a 5-day clopidogrel washout period was recommended for patients who received clopidogrel before angiographic analysis and in whom CABG was subsequently planned.

End Points and Definitions

Prespecified end points were assessed at 30 days and 1 year after the procedure and included death, MI, composite ischemia, unplanned revascularization for ischemia, and combinations of the above defined as composite

ischemia (major adverse cardiac events [MACEs]) and were adjudicated by a blinded clinical events committee.

In all patients undergoing CABG, diagnosis of perioperative MI required the following: (1) any creatine phosphokinase (CPK)-MB level of 10× or greater of the upper limit of normal (ULN) or CPK of 10× or greater of the ULN in the absence of MB determination within 24 hours of CABG and increased at least 50% over the most recent pre-CABG levels or (2) any CPK-MB level of 5× or greater of the ULN (or CPK ≥5× of the ULN in the absence of MB determination) within 24 hours of CABG and increased at least 50% over the most recent pre-CABG levels along with new significant (≥0.04 s) Q-waves in 2 or more contiguous electrocardiographic leads.

The somewhat strict ACUITY scale definitions for a bleeding event were as follows: reoperation for bleeding, reduction in hemoglobin concentration of 3 g/dL or greater with an overt source of bleeding (or ≥4 g/dL without), use of any blood product transfusion, and intracranial or intraocular bleeding.

Statistical Analysis

Continuous variables are summarized as means ± standard deviations and compared by using 2-sample *t* tests. Categorical variables are summarized with frequencies and percentages and compared by using χ^2 or Fisher's exact tests, where appropriate. Multivariable logistic regression was used to evaluate risk factors for death, MACEs, MI, and reintervention. Odds ratios (ORs) and 95% confidence intervals (CIs) are given. Event curves for postoperative survival, MACEs, MI, and reintervention are generated by using the Kaplan-Meier method, and comparison between groups is made with the log-rank test. To eliminate all differences between the groups, we further performed a propensity score analysis that was matched for sex, weight, hypertension, ST-segment deviation of 1 mm or greater, and the number of diseased vessels. The probability (propensity score) that a patient would undergo CABG or OPCAB according to the preprocedural variables was determined by using a saturated logistic regression model to take into account the different patient profiles. Each patient from the OPCAB group was then matched with 3 patients from the CABG group according to their propensity scores, resulting in 880 propensity-matched patients (220 in the OPCAB group and 660 in the CABG group) in whom early and late outcomes were determined.

Categorical variables were compared by using χ^2 or Fisher's exact tests. Continuous variables were compared by using the nonparametric Wilcoxon rank sum test. Time-to-event data are displayed by using Kaplan-Meier methodology and were compared with the log-rank test. All analyses were performed with SAS software (SAS Institute, Inc, Cary, NC).

Finally, allocation to treatment group for the present study was made on the basis of the intention to treat. Patients converted during the procedure from the off-pump technique to CABG with cardiopulmonary bypass were thus included in the OPCAB group.

RESULTS

Among a total of 13,819 patients with moderate- to high-risk ACSs in the ACUITY trial, a total of 1375 (9.9%) were triaged to isolated CABG. Among these, there were 231 patients who underwent initial operations without the use of cardiopulmonary bypass (the OPCAB group) and 1154 who underwent operations with cardiopulmonary bypass (the CABG group). There was no difference in initial randomization to antithrombotic regimen between the groups, and the initial antithrombotic regimen was included in the multivariable analysis model. There was also no difference between time from study drug cessation to the surgical procedure. All study antiaggregants were discontinued in a timely manner before surgical intervention (Table 1).

TABLE 1. Randomization for different antithrombotic regimens (n = 880)

Antithrombotic regimen	Off pump	On pump	P value
Randomized to heparin + IIb/IIIa	35.0% (77/220)	35.8% (236/660)	.8710
Randomized to bivalirudin + IIb/IIIa	35.0% (77/220)	30.6% (202/660)	.2417
Randomized to bivalirudin alone	30.0% (66/220)	33.6% (222/660)	.3615
Time from any study drug stop to CABG (h)	64.04 ± 82.59	88.22 ± 363.32	.1338
Time from heparin stop to CABG (h)	43.89 ± 65.41	157.12 ± 898.45	.2468
Time from bivalirudin stop to CABG (h)	64.86 ± 83.85	75.64 ± 122.48	.2570
Time from bivalirudin+IIb/IIIa stop to CABG (h)	89.91 ± 92.47	85.03 ± 104.24	.7320

CABG, Coronary artery bypass grafting.

Results Before Propensity Score Matching

Patients in the CABG group had more extensive coronary disease, with 2.59 ± 0.7 diseased vessels versus 2.44 ± 0.8 diseased vessels in the OPCAB group ($P = .007$); were more likely to present with ST-segment deviation of more than 1 mm (51.1% vs 43.0%, $P = .03$); and had a slightly higher body weight (85.1 ± 17.6 vs 82.7 ± 15.9 kg, $P = .04$). The complete baseline clinical and angiographic characteristics of the patients are displayed in Table 2.

At 1 month, there was no difference between groups in mortality (3.6% vs 3.2%, OPCAB vs CABG; $P = .76$), MI (7.3% vs 11.4, OPCAB vs CABG; $P = .07$), stroke (0.0%

vs 1.0%, OPCAB vs CABG; $P = .23$), acute renal injury (28.2% vs 31.5%, OPCAB vs CABG; $P = .39$), or MACEs (11.3% vs 14.1%, OPCAB vs CABG; $P = .28$). Patients undergoing OPCAB had a lower rate of non-Q-wave MI (3.2% vs 8.0%, $P = .01$) and a lower rate of bleeding events (43.6% vs 54.3%, $P = .001$) but required more unplanned coronary reinterventions (3.6% vs 1.0%, $P = .001$).

Late Outcome

At 1 year (up to 395 days), there was no difference between the groups in total or cardiac-related mortality, MI, stroke, unplanned reintervention, or MACEs (Table 3).

TABLE 2. Baseline clinical and angiographic characteristics of the study cohort (n = 1375)

	Off pump (n = 221)	On pump (n = 1154)	P value
Age at randomization (y)	64.66 ± 10.59 (221)	64.12 ± 10.17 (1154)	.47
Male sex	80.5% (178/221)	76.3% (881/1154)	.19
Weight (kg)	82.70 ± 15.98 (221)	85.06 ± 17.64 (1152)	.04
Diabetes	31.4% (69/220)	34.7% (398/1146)	.35
Insulin diabetes	11.8% (26/220)	11.1% (127/1146)	.72
Hypertension	71.0% (157/221)	65.6% (756/1153)	.12
Hyperlipidemia	54.1% (118/218)	50.7% (567/1118)	.37
Current smoker	28.3% (62/219)	27.7% (315/1136)	.87
Previous MI	24.8% (53/214)	24.1% (274/1135)	.86
Previous PTCA	22.7% (50/220)	21.3% (243/1143)	.65
Previous CABG	3.6% (8/221)	4.5% (52/1153)	.72
Renal insufficiency	22.9% (47/205)	17.2% (186/1082)	.06
Baseline cardiac biomarker increase	73.6% (153/208)	73.9% (797/1079)	.93
Baseline troponin increase	68.3% (136/199)	71.4% (740/1037)	.39
ST-segment deviation ≥ 1 mm	43.0% (95/221)	51.1% (590/1154)	.03
Baseline cardiac biomarker increase or ST-segment deviation	84.4% (178/211)	86.5% (959/1109)	.45
TIMI risk score			
Low (0–2)	11.3% (23/203)	11.5% (119/1034)	1.00
Intermediate (3–4)	51.2% (104/203)	55.2% (571/1034)	.31
High (5–7)	37.4% (76/203)	33.3% (344/1034)	.25
No. of diseased vessels	2.44 ± 0.77 (221)	2.59 ± 0.69 (1154)	.007
LAD disease	91.0% (201/221)	93.0% (1073/1154)	.32
LCX disease	77.8% (172/221)	82.8% (955/1154)	.08
RCA disease	75.6% (167/221)	83.5% (964/1154)	.006
LM disease	31.7% (70/221)	31.2% (360/1154)	.87
Multivessel disease	85.5% (189/221)	91.1% (1051/1154)	.013
Left ventricular ejection fraction (%)	54.01 ± 12.95 (165)	51.86 ± 13.44 (906)	.06

MI, Myocardial infarction; PTCA, percutaneous transluminal coronary angioplasty; CABG, coronary artery bypass grafting; TIMI, Thrombolysis in Myocardial Infarction; LAD, left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery; LM, left main artery.

In multivariable analysis we found that 1-month and 1-year mortality were not significantly different according to revascularization strategy (OR = 0.89 [95% CI, 0.3–2.67], $P = .98$, and OR = 1.57 [95% CI, 0.74–3.32], $P = .24$, for OPCAB vs CABG at 1 month and 1 year, respectively). However, OPCAB was associated with a significant increase in the rate of early unplanned reinterventions (OR = 4.1 [95% CI, 1.59–10.6], $P = .003$) and a lower rate of bleeding events (OR = 0.6 [95% CI, 0.46–0.84], $P = .002$).

Of note, 36 patients initially triaged for OPCAB eventually underwent operations with cardiopulmonary bypass. The exact cause of that alteration for each patient was unobtainable, and further study showed that although there were no preoperative differences between patients undergoing “standard” CABG and those who were converted to CABG (apart from the small difference of a higher percentage of male subjects in the converted group: 91.7% vs 76.3%, $P = .028$), these patients had higher rates of unplanned reinterventions both early (8.3% vs 1.0%, $P < .0001$) and late (11.2% vs 3.8%, $P = .02$) after the procedure compared with patients initially selected for standard CABG strategy. This verifies the notion that improper strategy selection with concomitant conversion from an off-pump to an on-pump procedure has its price.

Results After Propensity Score Matching

As described in the statistical analysis section, propensity score matching (1:3) was applied to adjust for differences between groups, yielding a total of 880 matched patients with ACSs (220 managed with OPCAB and 660 managed with CABG). The baseline clinical and angiographic characteristics of the 2 propensity-matched groups were balanced in all measured characteristics apart from a 6.3% difference in the extent of right coronary artery disease (Table 4). In the OPCAB group the mean number of grafts per patient was 2.8 ± 1.2 , whereas in the CABG group patients had a mean of 3.4 ± 1.03 grafts per patient ($P < .0001$). Exact operative data, such as the type of graft and exact number of vessels treated in the CABG group, could not be generated accurately from the ACUTY database configuration. The mean duration of hospitalization was 13.0 ± 10.9 days for the OPCAB group versus 13.0 ± 17 days for the CABG group ($P < .94$). There was also no difference in time from procedure to discharge between the groups (8.9 ± 10.2 vs 8.7 ± 6.8 days, OPCAB vs CABG; $P = .79$).

At 1 month, there was no difference in all-cause mortality (3.7% vs 3.6%, OPCAB vs CABG; $P = .99$), cardiac mortality, MACEs, stroke rate, and acute renal injury in patients managed with OPCAB versus CABG. The rates of MI and bleeding events were higher in the CABG group (12.1% vs 7.3%, $P = .055$, and 56.3% vs 43.7%, $P = .0005$, CABG vs OPCAB); however, the rate of

TABLE 3. Early and late clinical outcomes (n = 1375)

	Off pump (n = 221)	On pump (n = 1154)	P value
1-mo Outcomes (to 35 d)			
Major adverse cardiac events	11.3% (25)	14.1% (162)	.28
Death/MI	10.0% (22)	13.6% (157)	.14
Death	3.6% (8)	3.2% (37)	.76
Cardiac death	3.6% (8)	3.0% (35)	.65
Noncardiac death	0.0% (0)	0.1% (1)	.66
MI	7.3% (16)	11.4% (131)	.07
Q-wave MI	4.1% (9)	3.6% (41)	.71
Non-Q-wave MI	3.2% (7)	8.0% (91)	.01
Unplanned revascularization	3.6% (8)	1.0% (11)	.002
PCI	2.3% (5)	0.7% (8)	.03
CABG	1.4% (3)	0.3% (3)	.02
CVA	0.0% (0)	1.0% (11)	.23
TIA	0.0% (0)	0.3 (3)	1.00
Acute renal injury*	28.2% (53)	31.5% (323)	.39
Bleeding events†	43.6% (96)	54.3% (624)	.001
Reoperation for bleeding	0.9% (2)	1.1% (13)	.77
Blood product transfusion	35.4% (78)	41.4% (475)	.07
1-y Outcomes (to 395 d)			
Major adverse cardiac events	17.8% (39)	18.4% (211)	.76
Death/MI	15.1% (33)	15.9% (182)	.69
Death	6.9% (15)	5.3% (60)	.35
Cardiac death	4.1% (9)	3.8% (44)	.85
Noncardiac death	2.9% (6)	1.3% (14)	.08
MI	9.2% (20)	11.8% (135)	.24
Q-wave MI	4.1% (9)	3.7% (42)	.75
Non-Q-wave MI	5.1% (11)	8.4% (96)	.08
Unplanned revascularization	6.1% (13)	3.8% (42)	.11
PCI	4.7% (10)	3.5% (38)	.35
CABG	1.4% (3)	0.4% (5)	.09
CVA	0.0% (0)	1.0% (12)	.23
TIA	0.0% (0)	0.3 (3)	1.00

Rates are displayed as Kaplan–Meier percentage estimates (number of events). *MI*, Myocardial infarction; *PCI*, percutaneous coronary intervention; *CABG*, coronary artery bypass grafting; *CVA*, cerebrovascular accident; *TIA*, transient ischemic attack.

*Denotes a relative 25% increase or absolute 0.5 mg/dL increase in serum creatinine values after the procedure compared with baseline values. †Acute Catheterization and Urgent Intervention Triage Strategy (ACUTY) scale definition for bleeding: reoperation for bleeding, reduction in hemoglobin concentration of 3 g/dL or greater with an overt source of bleeding (or ≥ 4 g/dL without), use of any blood product transfusion, and intracranial/intraocular bleeding.

unplanned repeat revascularization for ischemia was higher in the OPCAB group (1.2% vs 3.7%, $P = .02$). At 1 year, there was no difference in all propensity-adjusted outcomes between the groups apart from non-Q-wave MI rates that were higher in the CABG group (9.2% vs 4.6%, $P = .03$). The outcomes of the multivariable analysis and propensity score analysis are provided in Table 5 and Figure 1.

DISCUSSION

An aggressive approach of early angiographic analysis with subsequent revascularization (by means of either

TABLE 4. Baseline clinical and angiographic characteristics after propensity matching (1:3), (n = 880)

	Off pump (n = 220)	On pump (n = 660)	P value
Age at randomization (y)	64.63 ± 10.61 (220)	64.90 ± 10.30 (660)	.74
Male sex	80.5% (177/220)	82.1% (542/660)	.61
Weight (kg)	82.72 ± 16.02 (220)	83.47 ± 15.41 (660)	.54
Diabetes	31.5% (69/219)	34.7% (228/657)	.41
Insulin diabetes	11.9% (26/219)	10.2% (67/657)	.52
Hypertension	70.9% (156/220)	72.0% (475/660)	.795
Hyperlipidemia	53.9% (117/217)	52.9% (338/639)	.81
Current smoker	28.4% (62/218)	27.2% (177/650)	.72
Previous MI	24.9% (53/213)	25.3% (164/647)	.93
Previous PTCA	22.8% (50/219)	22.4% (146/652)	.92
Previous CABG	3.6% (8/220)	4.9% (32/659)	.57
Renal insufficiency	23.0% (47/204)	18.8% (118/629)	.19
Baseline cardiac biomarker increase	73.4% (152/207)	73.9% (457/618)	.92
Baseline troponin increase	68.3% (136/199)	71.3% (424/595)	.47
ST-segment deviation ≥1 mm	42.7% (94/220)	43.3% (286/660)	.94
Baseline cardiac biomarker increase or ST-segment deviation	84.3% (177/210)	84.9% (533/628)	.82
TIMI risk score			
Low (0–2)	11.4% (23/202)	10.2% (60/589)	.69
Intermediate (3–4)	51.5% (104/202)	54.3% (320/589)	.51
High (5–7)	37.1% (75/202)	35.5% (209/589)	.67
No. of diseased vessels	2.44 ± 0.77 (220)	2.52 ± 0.75 (660)	.15
LAD disease	90.9% (200/220)	90.8% (599/660)	1.0000
LCX disease	77.7% (171/220)	79.8% (527/660)	.50
RCA disease	75.5% (166/220)	81.8% (540/660)	.05
LM disease	31.8% (70/220)	32.6% (215/660)	.87
Multivessel disease	85.5% (188/220)	88.6% (585/660)	.23
Left ventricular ejection fraction (%)	54.01 ± 12.95 (165)	51.79 ± 13.78 (675)	.07

See abbreviations in Table 2.

CABG or percutaneous coronary intervention), when appropriate, has been shown to be the superior approach for patients presenting with moderate- to high-risk ACSs¹⁶ and is recommended by current US and European guidelines for treating these patients.^{2,3} From the surgical perspective, the traditional convention of cooling off the patient by postponing the procedure during active ischemia has been challenged by a few recent studies. One, a retrospective analysis describing the outcomes of 12,988 unselected patients with ACSs, demonstrated that early CABG (performed in 267 of the patients) was an independent predictor of lower mortality (OR, 0.12).⁴ This report, as well as other communications describing the safety and efficacy of surgical revascularization during ACSs, has reinforced the role of CABG in this setting.^{5,6}

Experience with OPCAB has increased dramatically since the late 1990s, and it has been shown by numerous authors to be safe, reproducible, and effective for patients with coronary artery disease,^{17,18} including those considered to be at high operative risk for various reasons.^{19,20} Although many studies have attempted to identify the potential advantages of off-pump techniques over traditional approaches, most have been undersized or underpowered to detect differences in relevant outcome measures,

such as survival, MI, reintervention, or adverse neurologic events.

A recent prospective randomized trial comparing both techniques in a sizeable cohort of 2203 patients (mostly in nonurgent settings) found no difference in 30-day or 1-year mortality between patients undergoing OPCAB and those undergoing CABG, with a lower rate of the 1-year composite outcome of mortality, MI, and reintervention in the CABG group. This was accompanied by a superior graft patency rate in the CABG group among the 1371 patients who underwent follow-up coronary angiographic analysis (82.6% vs 87.8%, OPCAB vs CABG; $P < .01$).²¹ These results are consistent with a previous, smaller prospective randomized trial evaluating outcomes after off-pump procedures.⁹

In the subpopulation of actively ischemic patients, some speculate that off-pump CABG might reduce the extent of myocardial damage, perhaps through avoidance of ischemic arrest and reperfusion injury, earlier revascularization of the culprit lesion, attenuation of the no-reflow phenomenon, and reduction of myocardial edema.^{8–11} A recent report by Rastan and colleagues⁷ demonstrated that beating-heart techniques implemented during active ischemia reduced in-hospital adverse outcome measures, such as transfusion requirements, extensive inotropic support, prolonged

TABLE 5. Early and late clinical outcomes for the propensity-matched cohort (n = 880)

	Off pump (n = 220)	On pump (n = 660)	P value
1-mo Outcomes (to 35 d)			
Major adverse cardiac events	11.4% (25)	15.5% (102)	.13
Death/MI	10.0% (22)	14.7% (97)	.08
Death	3.7% (8)	3.6% (24)	.99
Cardiac death	3.7% (8)	3.3% (22)	.83
Noncardiac death	0.0% (0)	0.2% (1)	.56
MI	7.3% (16)	12.1% (79)	.055
Q-wave MI	4.1% (9)	3.1% (20)	.44
Non-Q-wave MI	3.2% (7)	9.0% (59)	.005
Unplanned revascularization	3.7% (8)	1.2% (8)	.02
PCI	2.3% (5)	0.8% (5)	.07
CABG	1.4% (3)	0.5% (3)	.16
Acute renal injury*	28.3% (53/187)	33.3% (198/594)	.21
Bleeding events†	43.7% (96)	56.3% (371)	.0005
Reoperation for bleeding	0.9% (2)	0.9% (6)	1.0
Blood product transfusion	35.6% (78)	42.3% (279)	.58
CVA	0.0% (0)	1.1% (7)	.20
TIA	0.0% (0)	0.3% (2)	1.0
1-y outcomes (to 395 d)			
Major adverse cardiac events	17.4% (38)	18.2% (120)	.69
Death/MI	14.7% (32)	16.2% (107)	.50
Death	6.9% (15)	5.2% (34)	.36
Cardiac death	4.1% (9)	4.3% (28)	.92
Noncardiac death	2.9% (6)	0.8% (5)	.02
MI	8.7% (19)	12.2% (80)	.15
Q-wave MI	4.1% (9)	3.1% (20)	.44
Non-Q-wave MI	4.6% (10)	9.2% (60)	.03
Unplanned revascularization	5.6% (12)	3.2% (20)	.09
PCI	4.2% (9)	2.7% (17)	.25
CABG	1.4% (3)	0.5% (3)	.16
CVA	0.0% (0/220)	1.1% (7/660)	.20
TIA	0.0% (0/220)	0.3% (2/660)	1.0

Rates are displayed as Kaplan–Meier percentage estimates (number of events). See abbreviations in Table 3. *Denotes a relative 25% increase or absolute 0.5 mg/dL increase in serum creatinine values after the procedure compared with baseline values. †Acute Catheterization and Urgent Intervention Triage Strategy (ACUTY) scale definition for bleeding: reoperation for bleeding, reduction in hemoglobin concentration of 3 g/dL or greater with an overt source of bleeding (or ≥4 g/dL without), use of any blood product transfusion, and intracranial/intraocular bleeding.

ventilation time, intensive care unit stay, and in-hospital stroke rate. A report by Biancari and associates¹² evaluated 314 patients with unstable angina, of whom half underwent operations without the use of cardiopulmonary bypass, and found no difference in early or intermediate mortality between the 2 groups (1.9% vs 3.9%, OPCAB vs CABG; $P = .33$) or in postoperative stroke rate, renal dysfunction, or MACEs. The only difference detected between groups was a lower transfusion requirement in the OPCAB group. Of note, after stratifying patients by their EuroSCORE level, the authors found an apparent early survival and early MACE benefit for those undergoing operations without cardiopulmonary bypass.

In this report we describe the early and midterm clinical outcomes of 1375 patients presenting with moderate- to

FIGURE 1. One-year outcomes (in percentages) for patients undergoing off-pump coronary artery bypass grafting (OPCAB) and coronary artery bypass grafting (CABG). MI, Myocardial infarction; MACE, major adverse cardiac events; CVA, cerebrovascular accident.

high-risk ACSs who underwent surgical myocardial revascularization with or without cardiopulmonary bypass in the large-scale, contemporary ACUTY trial. The major outcome difference between matched groups was in the early postoperative period, with patients undergoing OPCAB having lower bleeding events and MI rates and a higher incidence of unplanned coronary reinterventions, whereas at 1 year, patients undergoing OPCAB had a lower rate of non-Q-wave MIs. In multivariable analysis OPCAB revascularization again was associated with more unplanned early reinterventions. These results are consistent with previous studies performed in various patient populations.^{8-10,22-24} The lower perioperative MI rate might be explained by the minimization of myocardial injury attendant to the avoidance of ischemic arrest,^{7-10,22} whereas the higher reintervention rate might be related either to the more technically demanding nature of performing coronary anastomoses on the beating heart, to the greater tendency to perform incomplete revascularization with this approach, or both.^{7,25}

Our study has its limitations, including the fact that patients in the ACUTY trial were randomized to different initial antithrombotic regimens at presentation but not to the surgical approach. Selection of the exact surgical technique and of the revascularization strategy in general was left to the judgment of the clinical investigators and is thus subject to the limitations of selection bias. In addition, because the ACUTY trial was not a surgical trial, some covariates, such as vessel diameter, angiographic appearance, completeness of revascularization, the exact type of graft used or vessels treated, and the surgeon's level of experience, could not be included in the analysis. Finally, the follow-up period of 1 year might not suffice for true evaluation of either surgical strategy.

In conclusion, in this analysis of patients presenting with moderate- to high-risk ACSs and treated with early surgical revascularization, OPCAB was associated with reduced

myocardial injury and bleeding, along with more reinterventions early after the procedure. We believe that although these findings are representative of the actual tradeoffs associated with these 2 surgical approaches, they reaffirm the safety and legitimacy of both modalities in these high-risk patients.

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