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Stephen J. Lahey
University of Connecticut School of Medicine and Dentistry

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A Comparison of Long-Term Mortality for Off-Pump and On-Pump Coronary Artery Bypass Graft Surgery

Chuntao Wu, MD, PhD,
Department of Public Health Sciences, Penn State Hershey College of Medicine, Hershey PA (C.W. and F.T.C.)

Fabian T. Camacho, MS,
Department of Public Health Sciences, Penn State Hershey College of Medicine, Hershey PA (C.W. and F.T.C.)

Alfred T. Culliford, MD,
Department of Cardiothoracic Surgery, New York University Medical Center, New York, NY (A.T.C.)

Jeffrey P. Gold, MD,
College of Medicine, University of Toledo, Toledo, OH (J.P.G.)

Andrew S. Wechsler, MD,
Department of Cardiothoracic Surgery, Drexel University College of Medicine, Philadelphia, PA (A.S.W.)

Robert S.D. Higgins, MD,
Division of Cardiac Surgery, Ohio State University, Columbus, OH (R.S.D.H.)

Stephen J. Lahey, MD,
Division of Cardiothoracic Surgery, University of Connecticut Health Center, Farmington, CT (S.J.L.)

Craig R. Smith, MD,
Department of Surgery, Columbia University, New York, NY (C.R.S.)

Desmond Jordan, MD, and
Department of Anesthesiology, Columbia University, New York, NY (D.J.)

Edward L. Hannan, PhD
School of Public Health, University at Albany, State University of New York, Rensselaer, NY (E.L.H.)

Abstract

Correspondence to: Chuntao Wu, MD, PhD, Penn State Hershey College of Medicine, Academic Support Building, Suite 2200, A210, 600 Centerview Dr., Hershey, PA 17033, chuntao.wu@psu.edu, Tel: 717-531-4209, Fax: 717-531-5779.

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Background—The survival difference between off-pump and on-pump coronary artery bypass graft (CABG) surgery for follow-up longer than 5 years is not well understood. The objective of this study is to examine the difference in 7-year mortality after these two procedures.

Methods and Results—New York State's Cardiac Surgery Reporting System was used to identify the 2,640 off-pump and 5,940 on-pump isolated CABG patients discharged from July through December, 2000. The National Death Index was used to ascertain patients' vital statuses through 2007. A logistic regression model was fit to predict the probability of receiving an off-pump procedure using baseline patient characteristics. Off-pump and on-pump patients were matched with a 1:1 ratio based on the probability of receiving an off-pump procedure. Kaplan-Meier survival curves for the 2 procedures were compared using the propensity-matched data, and the hazard ratio for death for off-pump in comparison to on-pump procedures was obtained. In subgroup analyses, the significance of interactions between type of surgery and baseline risk factors was tested. In this study, 2,631 pairs of off-pump and on-pump patients were propensity matched. The 7-year Kaplan-Meier survival rates were 71.2% and 73.4% (P=0.07) for off-pump and on-pump surgery, respectively. The hazard ratio for death (off-pump vs. on-pump) was 1.10 (95% confidence interval: 0.99-1.21, P=0.07). No statistical significance was detected for the interaction terms between type of surgery and a number of different baseline risk factors.

Conclusions—The difference in long-term morality between on-pump and off-pump CABG surgery is not statistically significant.

Keywords

CABG; coronary artery disease; follow-up studies; mortality; off-pump surgery

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Previous studies have found that off-pump coronary artery bypass graft (CABG) surgery is more likely to be related to lower rates of graft patency[1-4] and complete revascularization[2] compared to on-pump CABG surgery. Therefore, off-pump surgery may be related to a higher rate of repeat revascularization[5-7] and mortality in the long run. [8] However, the relative benefit in long-term survival following off-pump and on-pump CABG surgery has not been thoroughly studied, and there is limited information on the relative risk of death in follow-up period of 5 years or more.[8]

Using the data of the New York State's Cardiac Surgery Reporting System (CSRS), we have examined the differences in mortality for up to 3 years between off-pump and on-pump CABG surgery.[9, 10] However, it is unknown whether the relative survival of the 2 surgical techniques during longer-term follow-up will be the same as it was observed in these 2 studies. Therefore, the purpose of this study is to examine the difference in 7-year mortality between off- pump and on-pump CABG surgery.

METHODS

Databases

This study used 2 major databases, the New York State's CSRS and the National Death Index (NDI). The CSRS is a state-wide registry that records all major cardiac surgical procedures performed in nonfederal hospitals in the State of New York. The CSRS has been in place since 1988, and it is managed by the State's Department of Health. For each cardiac surgery case, the discharging hospital collects detailed data on patient demographics, pre-procedural risk factors, procedural information, major post-procedural outcomes, and disposition at discharge. For procedural information, the database includes the utilization of cardiopulmonary bypass and the conversion of off-pump to on-pump surgery. The cardiac procedures submitted to the CSRS are matched to the State's statewide hospital discharge data to ensure the completeness of case reporting. In addition, samples of the medical records for reported cases are reviewed periodically by the State's utilization review organization to ensure the accuracy of the risk factors. The CSRS was used to identify the study population and to obtain baseline patient characteristics.

The NDI is managed by the National Center for Health Statistics. This database includes all death records in the United Sates. In this study, the NDI was used to determine patients' vital statuses using patients' social security numbers collected in the CSRS.

Study Population and Outcome

From the CSRS data, a total of 8,580 patients were identified as having undergone isolated CABG surgery with sternotomy and discharged between July 1 and December 31, 2000. The patients were classified as off-pump or on-pump patients based on the intent to treat. A total of 2,640 patients were initially treated by off-pump procedures, and 5,940 patients were initially treated by on-pump procedures. Among the 2,640 off-pump patients, conversions to on-pump surgery occurred in 43 (1.6%) patients. These 43 converted patients were treated as off-pump cases in the main analyses, but a sensitivity analysis was conducted with them in the on-pump group.

The outcome of interest in this study is mortality following surgery. The vital status of each patient was tracked from the date of surgery to December 31, 2007 using the NDI data. Every patient was followed for at least 7 years or until time of death, and the median length of follow-up was 7.2 years with an interquartile range of 7.0 - 7.4 years.

Statistical Analysis

First, the differences in baseline patient characteristics in the off-pump and on-pump patients were examined. The patient characteristics examined included age, sex, race and ethnicity, body surface area, body mass index (BMI), left main coronary artery disease (stenosis ≥ 50%), disease (stenosis ≥ 70%) of the 3 major epicardial coronary arteries, ejection fraction, history of myocardial infarction, hemodynamic state, various comorbidities, and history of coronary CABG surgery and percutaneuous coronary intervention (PCI). The differences in the prevalences of categorical baseline risk factors between off-pump and on-pump patients were examined using Pearson's chi-square test, and the means of continuous variables in the 2 groups of patients were compared using Student's t-test.

Next, propensity matching was conducted to balance the distribution of patient baseline characteristics between the off-pump and on-pump patients in order to control for potential treatment selection bias because of the non-randomized nature of this observational study.[11, 12] The first step in the matching process was to fit a logistic regression model, i.e., a propensity model, which included all baseline risk factors as predictors of receiving off-pump surgery. This model was then used to calculate each patient's probability of receiving off-pump surgery. The log-odds of this probability is the propensity score. Then the off-pump and on-pump patients were matched to each other at a 1:1 ratio on the closeness of propensity scores. For a matched pair, the difference in propensity scores had to be no more than 0.6 times the standard deviation of the propensity score.[13] To evaluate whether the baseline risk factors were well-balanced, the standardized differences between the 2 matched groups in the prevalences of risk factors examined. A standardized difference less than 10% for a risk factor is usually viewed as evidence that it was well balanced between the 2 treatment groups.

Using data from the pair-matched patients, the difference in survival between off-pump and on-pump surgery was examined using Kaplan-Meier survival analysis with a test suggested by Klein and Moeschberger.[14, 15] The hazard ratio for death for off-pump surgery in comparison to on-pump surgery was obtained from a Cox proportional hazards regression model with a robust sandwich estimator to account for the correlations within matched pairs that modeled the time to event (death) after the procedure using type of surgery as the single independent variable.[16, 17]

In addition, subgroup analyses were conducted to evaluate whether the relative risk of death following off-pump and on-pump surgery was dependent on the presence of certain pre-selected baseline risk factors (age, sex, left main coronary disease, number of diseased coronary vessels, ejection fraction, history of myocardial infarction, cerebrovascular disease, peripheral arterial disease, congestive heart failure, and diabetes). The significance of the interaction between a given risk factor and type of surgery was tested by fitting a Cox proportional hazards regression model with a robust sandwich estimator, in which the independent variables were type of surgery, the risk factor being examined, their interaction term, and other significant ($P<0.05$) baseline risk factors for death identified using a backwards selection approach.

A sensitivity analysis was conducted considering the possible impact of surgeons' experience on relative survival after off-pump and on-pump surgery. The risk-adjusted risks of the death between the 2 procedures were compared in a subset of matched patients, which consisted of 1,265 off-pump patients operated on by high-volume surgeons (upper quartile) who performed off-pump surgery in > 50% of their isolated CABG surgery cases and 1,137 on-pump patients operated on by high-volume surgeons who performed on-pump surgery in > 50% of their isolated CABG surgery cases.

All statistical analyses were conducted in SAS version 9.2 (SAS Institute, Cary, NC).

RESULTS

Table 1 presents the prevalences (means for continuous variables) of baseline risk factors in the 2,640 off-pump and 5,940 on-pump patients. The off-pump patients were slightly older, were more likely to have comorbidities such as cerebrovascular disease, peripheral arterial disease, left ventricular hypertrophy, congestive heart failure, extensively calcified ascending aorta, and renal failure, have a history of open heart surgery and percutaneous coronary intervention. The on-pump patients were slightly more likely to be Hispanic, have slightly larger body surface areas, be overweight or obese, have left main coronary disease and three-vessel disease, have a history of myocardial infarction within 7 days, have undergone cardiopulmonary resuscitation prior to surgery, have chronic obstructive pulmonary disease, and have been transferred as emergency patients to the operating room after diagnostic catheterization. Also, the mean number of anastomoses was higher for on-pump patients (3.34 vs. 2.69, $P<0.001$).

A total of 2,631 (99.7%) off-pump patients were pair-matched to on-pump patients. Table 2 shows that the distributions of baseline risk factors between the matched off-pump and on-pump patients were well balanced (all P values ≥ 0.25). The standardized differences in prevalences or means of all risk factors were ≤ 4.3%.

Among the 2,631 pair-matched patients, 48 (1.82%) off-pump and 70 (2.66%) on-pump patients died within 30 days following surgery. The hazard ratio (HR) for death within 30 days for off-pump in comparison to on-pump surgery was 0.68 (95% confidence interval (CI): 0.47-0.98), and it was marginally significant ($P=0.04$). During the follow-up until December 31, 2007, 782 off-pump and 725 on-pump patients died, and HR for death was 1.10 (95% CI: 0.99-1.21, $P=0.07$). The Figure shows that the respective 7-year survival rates for off-pump and on-pump surgery were 73.4% and 71.2% ($P=0.07$). In a sensitivity analysis in which the patients who were converted from off-pump to on-pump were regarded as on-pump patients, the hazard ratio for death within 30 days was 0.49 (95% CI: 0.33-0.72;

P<0.001), and the hazard ratio for death during the entire follow-up period was 1.10 (95% CI: 0.99-1.21, P=0.08).

Table 3 shows that the adjusted HRs ranges from 0.94 to 1.21 across all subgroups. The risk of death was significantly higher for off-pump surgery in patients who had ejection fractions of at least 40% (adjusted HR=1.18, P=0.01), and was marginally significant in females (adjusted HR = 1.21, P=0.04), patients who had multivessel disease (adjusted HR=1.13, P=0.03), and patients with no congestive heart failure (adjusted HR=1.16, P=0.03). But, all interaction term between surgery type and all examined risk factors were not statistically significant (P>0.05). Therefore there was no conclusive evidence that the relative risk of death following off-pump and on-pump surgery was dependent on the presence of a particular risk factor.

In the sensitivity analysis that included the 1,265 off-pump patients treated by high-volume surgeons who performed off-pump surgery in > 50% of their cases and 1,137 on-pump patients treated by high-volume surgeon who performed on-pump in > 50% of their cases, 331 off-pump and 285 on-pump patients died in the follow-up period until the end of 2007. The adjusted HR for death for off-pump compared to on-pump surgery was 1.12 (95% CI: 0.95-1.32, P=0.17).

DISCUSSION

In this propensity matched study, we found that the risk of death within 30 days of surgery was lower for off-pump compared to on-pump surgery and was marginally significant (HR=0.68, 95% CI: 0.47-0.98), P=0.04), but there was no difference in 7-year mortality following off-pump and on-pump CABG surgery was found (HR=1.10, 95% CI: 0.99-1.21, P=0.07). Also, there was a lack of decisive evidence that the difference in 7-year mortality following these 2 procedures was dependent on the presence of a number of baseline risk factors.

The observed lower risk of short-term mortality for off-pump surgery is consistent with the findings of our previous study that examined in-hospital/30-day mortality (adjusted odds ratio (OR) = 0.81, 95% CI: 0.68-0.97).[9] It is also consistent with the findings of a meta-analysis of observational studies by Wijeysundera and colleagues, which reported the OR for 30-day death was 0.72 (95% CI: 0.66-0.78) for off-pump compared to on-pump surgery.[7] In addition, there was a trend that the risk of 30-day death was lower for off-pump surgery in a meta-analysis of randomized clinical trials, though the difference was not statistically significant (OR=0.91, 95% CI: 0.45-1.83). [7]

The finding in this study that the difference in 7-year survival between off-pump and on-pump surgery was not statistically significant (HR=1.10, 95% CI: 0.99-1.21) is similar to the findings of other observational studies that examined long-term (≥ 5 years) mortality, although the findings of other studies varied with regard to statistical significance. In an observational study of 12,812 patients who underwent procedures in 1997-2006 in 2 hospitals and were followed through March 2007, Puskas and colleagues found nearly identical results to ours, with no difference in long-term mortality between off-pump and on-pump surgery (HR=1.09, 95% CI:0.95-1.25, P=0.23).[18] Nonetheless, the observational study by Puskas et al[18] and the current and past studies of our group[9, 10] showed a trend of higher risk of long-term mortality for off-pump surgery, though the P values were either not significant[9, 18] or marginally significant.[10] In a single institution observational study that followed patients for as long as 12 years with a median follow-up of roughly 5 years, Filardo et al. found that the risk of mortality was significantly higher for off-pump patients (HR=1.18, 95% CI: 1.02-1.38).[19] However, in another observational study consisting of 219

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patients in a single center, Gundry and colleagues reported no difference in 7-year between off-pump and on-pump surgery (80% vs. 79%, P=0.8).[20]

The differences in 5-year or longer-term mortality between the 2 surgical techniques were also not statistically significant in 4 randomized trials.[21-24] Puskas and colleagues found that the 7-year survival rates for off-pump and on-pump surgery were 83.7% and 73.7% (P=0.09), respectively, in a randomized trial that enrolled 200 patients.[21] In a trial of 281 low-risk patients, van Dijk and colleagues found the 5-year mortality rates between off-pump and on-pump surgery was not statistically significant (8.5% vs. 6.5%, P=0.65).[22] In another trial of 308 patients conducted by Hueb and colleagues, the respective 5-year mortality rates for off-pump and on-pump surgery were 8.4% and 5.2% (P=0.18).[23] In a pooled analysis of 2 trials, using the data of 401 patients in a follow-up period averaging 6 years, Angelini and colleagues found no difference in mortality between off-pump and on-pump surgery (HR=1.24, 95% CI: 0.72-2.15, P=0.44).[24] However, in a meta-analysis of 11 randomized controlled trials with follow-up ranging from 1 to 6 years[22, 24-33], Takagi and colleagues found that off-pump surgery was associated with increased mortality compared to on-pump surgery (relative risk=1.37, 95% CI: 1.04-1.81, P=0.02).[8]

Thus, none of the long-term studies shows that there is a significantly higher risk of long-term mortality for off-pump surgery, but the meta-analysis suggests that there may be a survival advantage in favor of on-pump surgery. [8] However, the heterogeneity of the results of the long-term mortality studies also suggests that there is no definitive data in favor of long-term survival for either of the 2 surgical techniques.

In addition to examining the overall relative risk of death between off-pump and on-pump surgery, a subgroup analysis was conducted to test the significance of interactions between surgery type and a number of baseline risk factors. None of the interaction terms was statistically significant, therefore, no conclusive evidence was found to support that the relative risk of death between the 2 procedures is different across subgroups of patients, even though significant or marginally significant HRs were observed in 4 subgroups of patients who had ejection fraction at least 40%, were females, had multivessel disease, and had no congestive heart failure.

When the comparison was limited to the off-pump and on-pump patients who were operated on by high-volume surgeons who performed more off-pump and on-pump surgery, respectively, the adjusted HR was 1.12 (P=0.17). Therefore, the result of this sensitivity analysis was consistent with the overall relative risk of death (HR=1.10, P=0.07).

A few advantages and limitations of this study are noteworthy when its results are considered along with other studies. First, a major advantage is that this study is population-based. This study included all eligible patients treated by any surgeons in any nonfederal cardiac surgery programs in New York during the study period. Therefore the generalizability of this study is less likely to be of problem. Second, the rigorous data collection and validation of the CSRS data ensures the quality of the data. Third, this study evaluated the relative survival between off-pump and pump CABG surgery in real-world practice. It can provide useful information complementary to the results of randomized trials.[34, 35]

As for limitations, the most important one is that the treatments were not randomized as in clinical trials. To control for possible treatment selection bias, a propensity matching was conducted to ensure the baseline risk factors evenly distributed between the matched patients. Although the possibility of selection bias can not be eliminated with the use of propensity matching, the propensity analysis improves the validity of this study. Second, to obtain long-term data on survival, this study had to use the data of patients who underwent procedures a decade ago. Therefore, the improvement in both off-pump and on-pump CABG surgery over time needs to be considered when the results of this study are extrapolated in the context of current clinical practice.

In summary, this study found that the difference in 7-year survival between off-pump and on-pump CABG surgery was not statistically significant. The finding adds more information to the knowledge on the outcomes of the 2 surgical techniques.

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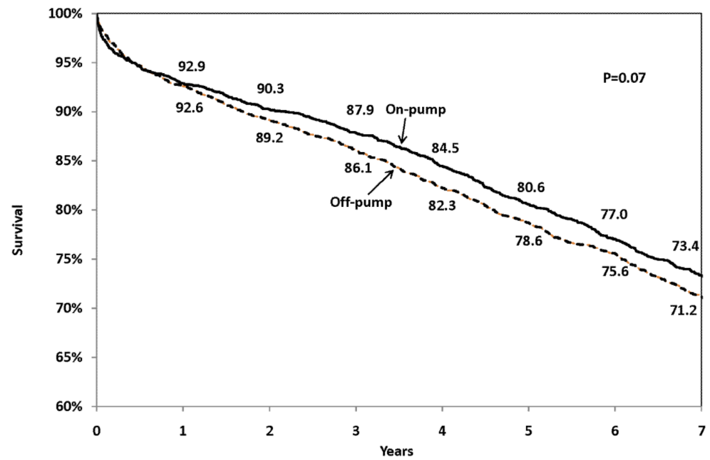

No. At Risk								
On-Pump	2631	2444	2375	2312	2223	2120	2027	1930
Off-Pump	2631	2437	2346	2266	2164	2071	1988	1873

Figure.

Kaplan-Meier survival curves for propensity matched off-pump and on-pump patients during 7-year follow-up.

Table 1

Baseline risk factors in the patients.*

Risk Factor	Off-Pump (N = 2,640)	On-Pump (N = 5,940)	P-Value
Mean age (yr, mean±SD)	67.7±11.0	65.7±10.5	<0.001
Age group (yr) , n (%)			
<50	168(6.4)	439(7.4)	<0.001
50-59	444(16.8)	1,247(21.0)	
60-69	742(28.1)	1,853(31.2)	
70-79	909(34.4)	1,932(32.5)	
≥80	377(14.3)	469(7.9)	
Female sex, n (%)	787(29.8)	1,660(27.9)	0.08
Race/ethnicity, n (%)			<0.001
Hispanic	125(4.7)	355(6.0)	
Non-Hispanic white	2,274(86.1)	5,050(85.0)	
Non-Hispanic black	166(6.3)	287(4.8)	
Non-Hispanic other race	75(2.8)	248(4.2)	
Body surface area (m^2, mean±SD)	1.98±0.2	2.01±0.2	<0.001
Body mass index (kg/m^2), n (%)			<0.001
<18.5	26(1.0)	42(0.7)	
18.5-24.99	708(26.8)	1,345(22.6)	
25.0-29.99	1,116(42.3)	2,565(43.2)	
30.0-34.99	525(19.9)	1,334(22.4)	
35.0-39.99	184(7.0)	453(7.6)	
≥40.0	81(3.1)	201(3.4)	
Left main coronary artery disease (stenosis ≥ 50%), n (%)	604(22.9)	1,557(26.2)	0.001
Number of diseased vessels (stenosis ≥ 70%), n (%)			<0.001
0 or 1	488(18.5)	702(11.8)	
2		808(30.6)	1,744(29.4)
3		1,344(50.9)	3,494(58.8)
Ejection fraction, n (%)			0.05
<20%	31(1.2)	101(1.7)	
20-29%	185(7.0)	371(6.2)	
30-39%	366(13.9)	781(13.1)	
40-49%	640(24.2)	1,363(22.9)	
≥50%	1,373(52.0)	3,244(54.6)	
Missing	45(1.7)	80(1.3)	
Previous myocardial infarction, n (%)			0.03
≤23 hours before treatment	37(1.4)	80(1.3)	
1-7 days before treatment	374(14.2)	972(16.4)	
8-20 days before treatment	172(6.5)	396(6.7)	
≥21 days before treatment	815(30.9)	1,666(28.0)	

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Risk Factor	Off-Pump (N = 2,640)	On-Pump (N = 5,940)	P-Value
No previous myocardial infarction	1,242(47.0)	2,826(47.6)	
Hemodynamic state, n (%)			0.59
Stable	2,613(99.0)	5,866(98.8)	
Unstable	19(0.7)	56(0.9)	
Shock	8(0.3)	18(0.3)	
Cardiopulmonary resuscitation, n (%)	0 (0.0)	10 (0.2)	0.04
Cerebrovascular disease, n (%)	549(20.8)	1,034(17.4)	<0.001
Peripheral arterial disease, n (%)	308(11.7)	594(10.0)	0.02
Electrocardiographic evidence of left ventricular hypertrophy, n (%)	345(13.1)	625(10.5)	<0.001
Congestive heart failure, n (%)			<0.001
At current admission	534(20.2)	650(10.9)	
Before current admission	147(5.6)	345(5.8)	
None	1,959(74.2)	4,945(83.2)	
Malignant ventricular arrhythmia, n (%)	40(1.5)	91(1.5)	0.95
Chronic obstructive pulmonary disease, n (%)	411(15.6)	1,015(17.1)	<0.001
Extensively calcified ascending aorta, n (%)	177(6.7)	244(4.1)	<0.001
Diabetes, n (%)	833(31.5)	1,922(32.3)	0.46
Hepatic failure, n (%)	3(0.1)	2(0.0)	0.16
Renal Failure, n (%)			<0.001
Requiring dialysis	61(2.3)	72(1.2)	
Creatinine >2.5 mg/dl (220 μmol/liter)	65(2.5)	85(1.4)	
No renal failure	2,514(95.2)	5,783(97.3)	
History of open heart operations, n (%)	194(7.3)	287(4.8)	<0.001
Emergency transfer to operating room after diagnostic catheterization, n (%)	25(0.9)	90(1.5)	0.04
Emergency transfer to operating room after percutaneous coronary intervention, n (%)	9(0.3)	33(0.5)	0.19
Percutaneous coronary intervention, this admission, n (%)	42(1.6)	69(1.2)	0.10
Percutaneous coronary intervention, before this admission, n (%)	560(21.2)	966(16.3)	<0.001
Stent thrombosis, n (%)	33(1.3)	83(1.4)	0.59

*Plus–minus values are means±SD. Because of rounding, percentages may not total 100.

Table 2

Baseline risk factors in the propensity matched patients.*

Risk Factor	Off-Pump (N = 2,631)	On-Pump (N = 2,631)	Standardized Difference (%)	P-Value
Mean age (yr, mean±SD)	67.7±11.0	67.7±10.7	−0.3	0.90
Age group (yr) , n (%)				0.40
<50	167(6.3)	147(5.6)	3.0	
50-59	443(16.8)	457(17.4)	−1.6	
60-69	741(28.2)	756(28.7)	−1.1	
70-79	908(34.5)	923(35.1)	−1.3	
≥80	372(14.1)	348(13.2)	2.6	
Female sex, n (%)	784(29.8)	771(29.3)	1.1	0.69
Race/ethnicity, n (%)				0.77
Hispanic	125(4.8)	121(4.6)	0.9	
Non-Hispanic white	2,265(86.1)	2,283(86.8)	−2.0	
Non-Hispanic black	166(6.3)	149(5.7)	2.5	
Non-Hispanic other race	75(2.9)	78(3.0)	−0.6	
Body surface area (m^2, mean±SD)	1.98 (0.24)	1.98 (0.24)	−0.4	0.80
Body mass index (kg/m^2), n (%)				0.94
<18.5	26(1.0)	25(1.0)	0.0	
18.5-24.99	703(26.7)	711(27.0)	−0.7	
25.0-29.99	1,113(42.3)	1,078(41.0)	2.6	
30.0-34.99	524(19.9)	546(20.8)	−2.2	
35.0-39.99	184 (7.0)	191(7.3)	−1.2	
≥40.0	81(3.1)	80(3.0)	0.6	
Left main coronary artery disease (stenosis ≥ 50%), n (%)	602(22.9)	623(23.7)	−1.9	0.49
Number of diseased vessels (stenosis ≥ 70%), n (%)				1.00
0 or 1	483(18.4)	481(18.3)	0.3	
2	806(30.6)	808(30.7)	−0.2	
3	1,342(51.0)	1,342(51.0)	0.0	
Ejection fraction, n (%)				0.91
<20%	31(1.2)	38(1.4)	−1.8	
20-29%	184(7.0)	182(6.9)	0.4	
30-39%	364(13.8)	375(14.3)	−1.4	
40-49%	639(24.3)	651(24.7)	−0.9	
≥50%	1,369(52.0)	1,346(51.2)	1.6	
Missing	44(1.7)	39(1.5)	1.6	
Previous myocardial infarction, n (%)				0.98
≤23 hours before treatment	36(1.4)	35(1.3)	0.9	
1-7 days before treatment	374(14.2)	389(14.8)	−1.7	
8-20 days before treatment	171(6.5)	170(6.5)	0.0	

Risk Factor	Off-Pump (N = 2,631)	On-Pump (N = 2,631)	Standardized Difference (%)	P-Value
≥21 days before treatment	810(30.8)	816(31.0)	−0.4	
No previous myocardial infarction	1,240(47.1)	1,221(46.4)	1.4	
Hemodynamic state, n (%)				0.67
Stable	2,604(99.0)	2,600(98.8)	1.9	
Unstable	19(0.7)	19(0.7)	0.0	
Shock	8(0.3)	12(0.5)	−3.3	
Cardiopulmonary resuscitation, n (%)	0(0)	2(0.1)	−3.8	0.50
Cerebrovascular disease, n (%)	545(20.7)	546(20.8)	−0.2	0.97
Peripheral arterial disease, n (%)	305(11.6)	309(11.7)	−0.3	0.86
Electrocardiographic evidence of left ventricular hypertrophy, n (%)	341(13.0)	331(12.6)	1.2	0.68
Congestive heart failure, n (%)				0.29
At current admission	526(20.0)	482(18.3)	4.3	
Before current admission	147(5.6)	145(5.5)	0.4	
None	1,958(74.4)	2,004(76.2)	−4.2	
Malignant ventricular arrhythmia, n (%)	40(1.5)	46(1.7)	−1.6	0.51
Chronic obstructive pulmonary disease, n (%)	410(15.6)	441(16.8)	−3.3	0.25
Extensively calcified ascending aorta, n (%)	175(6.7)	166(6.3)	1.6	0.61
Diabetes, n (%)	831(31.6)	814(30.9)	1.5	0.61
Hepatic failure, n (%)	3(0.1)	2 (0.1)	0.8	0.65
Renal Failure, n (%)				0.41
Requiring dialysis	60(2.3)	53(2.0)	2.1	
Creatinine >2.5 mg/dl (220 μmol/liter)	63(2.4)	51(1.9)	3.4	
No renal failure	2,508(95.3)	2,527(96.0)	−3.4	
History of open heart operations, n (%)	190(7.2)	179(6.8)	1.6	0.55
Emergency transfer to operating room after diagnostic catheterization, n (%)	25(1.0)	25(1.0)	0.0	1.00
Emergency transfer to operating room after percutaneous coronary intervention, n (%)	9(0.3)	11(0.4)	−1.6	0.65
Percutaneous coronary intervention, this admission, n (%)	41(1.5)	37(1.4)	1.7	0.65
Percutaneous coronary intervention, before this admission, n (%)	555(21.1)	546(20.8)	0.7	0.76
Stent thrombosis, n (%)	33(1.3)	32(1.2)	0.9	0.90

[*] Plus–minus values are means±SD. Because of rounding, percentages may not total 100.

Table 3

Subgroup-specific hazard ratios for death after off-pump CABG surgery as compared with on-pump surgery.*

	No. of Deaths/Total Cases		7-year KM Survival (%)			Adjusted Hazard Ratio for Death (Off- vs. On-Pump) †		P-Value for Interaction
Patient Group	**Off-Pump**	**On-Pump**	**Off-Pump**	**On-Pump**	**P-Value**	**Hazard Ratio (95% CI)**	**P-value**	
Age (yr)								
<60	83/610	70/604	86.6	89.2	0.32	1.16(0.85,1.58)	0.35	0.69
60-69	163/741	165/756	78.8	79.1	0.92	0.98(0.79,1.22)	0.86	
70-79	326/908	302/923	65.1	68.1	0.13	1.14(0.97,1.34)	0.12	
80+	210/372	188/348	45.4	46.8	0.42	1.13(0.92,1.38)	0.24	
Sex								
Female	273/784	245/771	65.9	69.1	0.17	1.21(1.01,1.45)	0.04	0.22
Male	509/1,847	480/1,860	73.4	75.1	0.23	1.05(0.93,1.19)	0.44	
Left main coronary disease								
Yes	223/602	202/623	64.3	68.5	0.10	1.18(0.97,1.44)	0.10	0.42
No	559/2,029	523/2,008	73.2	74.8	0.25	1.07(0.95,1.21)	0.26	
Number of diseased vessels								
2, 3	679/2,148	622/2,150	69.1	72.0	0.04	1.13(1.01,1.26)	0.03	0.22
0, 1	103/483	103/481	80.1	79.2	0.92	0.94(0.71,1.24)	0.66	
Ejection fraction								
<40%	234/579	258/595	60.3	58.0	0.26	0.95(0.79,1.15)	0.62	0.07
40%+	534/2,008	454/1,997	74.4	78.0	0.003	1.18(1.04,1.34)	0.01	
Previous myocardial infarction								
Yes	476/1,391	456/1,410	66.9	68.8	0.26	1.12(0.97,1.28)	0.11	0.79
No	306/1,240	269/1,221	75.9	78.5	0.12	1.08(0.92,1.27)	0.33	
Cerebrovascular disease								
Yes	243/545	238/546	56.0	57.7	0.58	1.05(0.87,1.27)	0.59	0.57
No	539/2,086	487/2,085	75.1	77.4	0.07	1.12(0.99,1.27)	0.06	
Peripheral arterial disease								
Yes	162/305	151/309	47.5	52.4	0.25	1.15(0.91,1.45)	0.23	0.67
No	620/2,326	574/2,322	74.2	76.1	0.13	1.09(0.97,1.22)	0.15	

Patient Group	No. of Deaths/Total Cases		7-year KM Survival (%)			Adjusted Hazard Ratio for Death (Off- vs. On-Pump) †		P-Value for Interaction
	Off-Pump	On-Pump	Off-Pump	On-Pump	P-Value	Hazard Ratio (95% CI)	P-value	
Congestive heart failure								
Yes	306/673	301/627	55.0	54.2	0.46	1.02(0.86,1.21)	0.81	0.25
No	476/1,958	424/2,004	76.7	79.3	0.02	1.16(1.02,1.32)	0.03	
Diabetes								
Yes	306/831	290/814	63.7	65.8	0.51	1.09(0.93,1.29)	0.29	0.92
No	476/1,800	435/1,817	74.6	76.7	0.09	1.11(0.97,1.26)	0.14	

†Risk factors adjusted for included age, race/ethnicity, ejection fraction, left main coronary disease, cerebrovascular disease, peripheral arterial disease, congestive heart failure, chronic obstructive pulmonary disease, diabetes, and renal failure.