Observational Study

Effect of different surgical type of coronary artery bypass grafting on kidney injury
A propensity score analysis

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Abstract

Acute kidney injury (AKI) after coronary artery bypass grafting (CABG) is associated with a less favorable outcome. Off-pump surgery results in lower kidney dysfunction than conventional on-pump arrest surgery. On-pump arrest surgery results in a lower revascularization rate compared with off-pump surgery. On-pump beating heart (OPBH) CABG combines the advantages of beating heart surgery and cardiopulmonary bypass. This study compared the renal outcomes of 3 cardiac surgical methods. From January 2010 to December 2012, 373 patients who underwent on-pump CABG were enrolled. Propensity analysis was performed to compare the postoperative outcomes of postoperative AKI, renal replacement therapy (RRT), intensive care unit (ICU) stay, mortality, and extubating time. In total, 98 patients received conventional on-pump surgery, 160 received OPBH surgery, and 115 received off-pump surgery. The Society of Thoracic Surgeons scores of these 3 groups were 6.1 ± 13.6, 7.4 ± 13.6, and 5.6 ± 10.9, respectively. Propensity analysis revealed lower AKI incidence in the off-pump group than in the on-pump surgery group. No substantial differences were observed in mortality, RRT, and the ICU stay between the off-pump and OPBH surgery groups. Among the 3 surgical methods, off-pump surgery results in lower AKI incidence. The short-term outcome, including kidney function, of OPBH surgery is similar to that of the off-pump group. Therefore, OPBH surgery is a considerable choice for patients with a high surgical risk.

Abbreviations: AKI = acute kidney injury, CABG = coronary artery bypass grafting, CI = confidence interval, Cr = creatinine, IABP = intra-aortic balloon pump, ICU = intensive care unit, KDIGO = Kidney Disease Improving Global Outcomes, LIMA = left internal mammary artery, OPBH = on-pump beating heart, OR = odds ratio, RRT = renal replacement therapy, STS score = Society of Thoracic Surgeons score.

Keywords: acute kidney injury, coronary artery bypass grafting, off-pump, on-pump

1. Introduction

Acute kidney injury (AKI) affects 12% to 50% of patients undergoing coronary artery bypass grafting (CABG).[1–5]

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Moreover, 2% to 11.2% patients with an increased mortality rate require renal replacement therapy (RRT).[6,7] Despite advances in cardiac surgery management, postoperative AKI still results in high short-term mortality, a complicated hospital course, high medical expenditure, and long-term dialysis dependence.[8] Age, sex, diabetes mellitus, congestive heart failure, chronic kidney disease, peripheral atherosclerosis, and chronic obstructive pulmonary disease are the risk factors for post-CABG AKI.[1,9] Several clinical trials have compared the effect of off-pump CABG and on-pump CABG on renal dysfunction.[10–12] Off-pump method had less incidence of AKI compared with on-pump arrest method. A recent study established on-pump beating heart (OPBH) surgery by combining standard on-pump surgery and off-pump surgery; the highest benefits of OPBH surgery are hemodynamic stability and the absence of cardioplegic arrest guaranteed during extensive heart manipulation, particularly for unstable, high-risk patients.[13] However, no previous study has compared the renal outcomes of the 3 surgical types. This study compared the incidence rates of AKI, RRT, and mortality after cardiac surgery.

2. Methods

2.1. Study design and patient population

This post hoc analysis of a prospectively collected database was approved by the Institutional Review Board of Chang Gung Memorial Hospital. Patient records were anonymized and analyzed, and individual consents were waived. The aforementioned database

comprised the medical records of 440 consecutive patients who received isolated CABG between January 2010 and December 2012 in a tertiary referral hospital. To clarify renal outcomes, patients with end-stage renal disease, confirmed AKI, and extracorporeal membrane oxygenation before surgery were excluded. Those who underwent dialysis before surgery and those with missing perioperative creatinine (Cr) data were also excluded. In total, 373 patients were enrolled into this study.

2.2. Data collection and definitions

The clinical characteristics, demographic data, and Society of Thoracic Surgeons (STS) score were extracted from the database. The baseline Cr level was defined as the preoperative value obtained on the date closest to the operation date. The primary outcome was postoperative AKI within 7 days. According to the definition provided in the Kidney Disease Improving Global Outcomes guidelines (KDIGO), AKI was diagnosed based on the following conditions: an increase in serum Cr of over 0.3 mg/dL within 48 hours or an increase in Cr exceeding the baseline by 1.5 times.[14] The outcomes of the incidence of AKI, RRT, mortality, duration of ventilator usage, and intensive care unit (ICU) stay were compared among the different surgical types. Urgent and emergent operation was defined according to EuroSCORE.[15] Shock was defined as hypotension with systolic arterial blood pressure of 90 mm Hg, despite adequate fluid resuscitation.

2.3. Surgical technique and postoperative care

All surgeons in our institution are familiar with all 3 techniques; the choice of off-pump, OPBH, or conventional cardioplegic arrest CABG depended on the preference of the individual surgeons. In both on-pump cohorts, cardiopulmonary bypass was established in a similar manner through the use of pulsatile flow. In the conventional CABG group, myocardial protection was obtained using 1 L of cold blood cardioplegia delivered antegradely or retrogradely; this process was repeated every 30 minutes, as necessary. In the OPBH group, commercially available stabilizers were used, and intracoronary artery shunts were used in all anastomosis connections. No conversion of OPBH to conventional CABG was performed during the study period.

2.4. Statistical analysis

Data are presented as mean ± standard deviation for continuous data and number (percentage) for categorical data. We compared the baseline characteristics and the surgical details of the study patients among the different surgical methods by using 1-way analysis of variance for continuous variables or the Fisher exact test for categorical variables. To control for confounding factors when comparing outcomes among the different surgical methods, we performed propensity score subclassification analyses.[16] We calculated the propensity score using the following covariates that are associated with AKI: age, sex, preoperative Cr level, cardiac ejection fraction, emergent/urgent operation, use of intra-aortic balloon pump (IABP), preoperative ventilator use, diabetes mellitus, recent myocardial infarction, shock, and chronic obstructive pulmonary disease. The propensity score was further equally divided into a quintile and was treated as a stratum variable in the logistic regression model performed for comparing the categorical outcomes (ie, in-hospital death or AKI) among the different surgical methods. For comparing the continuous

outcomes (ie, extubation hours or ICU duration), the quintile of propensity score was treated as a clustered variable (the second level), and the averaged intercept of each quintile was allowed to vary (random effect) in the linear mixed-effect model. The data were analyzed using SPSS 22 (IBM SPSS, Armonk, New York, NY: IBM Corp).

3. Results

3.1. Characteristics of the study population

A total of 373 patients with a mean age of 64.1 ± 11.3 years and including 307 (82.6%) men were investigated. All baseline characteristics are listed in Table 1. No significant differences were observed in age, sex, and preoperative renal and liver functions among the different surgical groups. A preoperative heart condition, such as the functional class of heart function, ejection fraction, IABP, recent myocardial infarction, and shock, was similar among these groups. The prevalence of chronic obstructive pulmonary disease was higher in the OPBH group than in the other groups (P = .022). The STS scores of mortality risk and renal failure were 6.5 ± 12.8 and 7.8 ± 13.4, respectively. No substantial differences were observed in the STS scores of mortality (P = .462) and renal failure (P = .689) among the 3 groups.

3.2. Surgical details

No significant differences were observed in left main coronary vessel disease, use of the left internal mammary artery (LIMA), and redo operation among all groups (Table 2). Patients in the on-pump arrest group were less likely to undergo emergent/urgent operations than patients in the OPBH and off-pump groups, although this trend was insignificant (17.3%, 29.4%, and 27%, respectively; P = .081). Compared with patients in the on-pump arrest or OPBH groups, patients in the off-pump group underwent bypass with fewer grafts (3.2 ± 0.7, 3.1 ± 0.7, and 2.8 ± 0.9, respectively; P < .001), had the highest levels of hemoglobin during cardiopulmonary bypass (7.1 ± 1.4, 7.7 ± 1.4, and 9.7 ± 1.5 g/dL, respectively; P < .001), and had a minimal volume of blood transfusion (9.1 ± 6.4, 7.2 ± 6.3, and 3.6 ± 4.2 units, respectively; P < .001). The time taken for cardiopulmonary bypass was 133.5 ± 60.3 and 110.6 ± 40.3 minutes in the on-pump arrest and OPBH groups, respectively.

3.3. Postoperative complications and outcome

Table 3 shows the propensity score subclassification analysis of in-hospital death. The risk of in-hospital death was comparable among the 3 groups (the on-pump arrest group vs the OPBH group, P = .762; the on-pump arrest group vs the off-pump group, P = .946; the OPBH group vs the off-pump group, P = .759). In this study, AKI of any severity occurred in 98 patients (26.3%) within 7 days after surgery. As shown in Table 4, the incidence of AKI was higher in the on-pump arrest group than in the off-pump group (odds ratio [OR] 2.67, 95% confidence interval [CI] 1.35–5.26, P = .005). No significant difference was observed in AKI incidence between either the OPBH and off-pump groups (P = .066), or the on-pump arrest and OPBH groups (P = .162). However, as shown in Table 5, hemodialysis risk was comparable among these groups (the on-pump arrest group vs the OPBH group, P = .898; the on-pump arrest group vs the off-pump group, P = .811; the OPBH group vs the off-pump group, P = .547). The results are also shown in Fig. 1.

Table 1

Baseline characteristics of patients who underwent conventional arrest coronary artery bypass surgery by surgical method.

Variable	On-pump arrest (n=98)	On-pump beating (n=160)	Off-pump (n=115)	P
Preoperative demographic data				
Age, y	63.1±10.7	64.3±11.6	64.4±11.4	.639
Female	20 (20.4)	26 (16.3)	20 (17.4)	.688
Diabetes mellitus	45 (45.9)	89 (55.6)	56 (48.7)	.271
Hypertension	77 (78.6)	128 (80.0)	88 (76.5)	.785
Peripheral arterial disease	9 (9.2)	12 (7.5)	8 (7.0)	.829
Old stroke	15 (15.3)	19 (11.9)	22 (19.1)	.257
Atrial fibrillation	9 (9.2)	16 (10.0)	4 (3.5)	.106
Chronic obstructive pulmonary disease	6 (6.1)	25 (15.6)	8 (7.0)	.022
Smoker	62 (63.3)	93 (58.1)	66 (57.4)	.648
Hemoglobin, g/dL	12.6±2.3	12.7±2.1	12.8±2.3	.876
Serum creatinine, mg/dL	1.22±1.05	1.25±0.91	1.18±0.74	.856
Albumin, g/L	3.9±0.4	3.9±0.4	4.0±0.4	.470
hs-CRP, mg/dL	19.3±26.5	24.4±38.0	18.4±31.3	.468
HbA1c, %	6.7±1.5	6.7±1.5	6.6±1.4	.679
ALT, units/L	41.0±86.3	28.7±20.1	27.9±22.3	.078
Preoperative heart condition				
Congestive heart failure Fc III /IV	18 (18.4)	25 (15.6)	13 (11.3)	.343
Ejection fraction, %	52.7±16.0	51.5±16.2	55.3±14.6	.139
Recent myocardial infarction	44 (44.9)	81 (50.6)	46 (40.0)	.216
Previous PCI	41 (41.8)	68 (42.5)	56 (48.7)	.510
Ventilator support	7 (7.1)	18 (11.3)	6 (5.2)	.199
IABP	12 (12.2)	19 (11.9)	8 (7.0)	.327
Shock	13 (13.3)	24 (15.0)	9 (7.8)	.196
Preoperative scores				
STS-risk of mortality	6.1±13.6	7.4±13.6	5.6±10.9	.462
STS-renal failure	7.4±13.8	8.5±13.3	7.3±13.2	.689

ALT = alanine transaminase, Fc = functional class, HbA1c = hemoglobin A1c, hs-RP = high-sensitivity C-reactive protein, IABP = intra-aortic balloon pump, PCI = percutaneous coronary intervention, STS = Society of Thoracic Surgeons.

Patients in the off-pump group received shorter extubation hours than those in the on-pump arrest group (23.0±44.8 vs 41.6±67.8 h; P = .017). However, no differences were observed between the on-pump arrest and OPBH groups, and between the OPBH and off-pump groups (P = .103 and P = .356, respectively, as presented in Supplement Table 1, http://links.lww.com/MD/B934). No significant difference was observed in ICU stay among these groups (as illustrated in Supplement Table 2, http://links.lww.com/MD/B934). The results are also illustrated in Fig. 2.

4. Discussion

Postcardiac surgery AKI is a part of cardiorenal syndrome and reflects the cumulative consequences of numerous perioperative factors that include ischemia–reperfusion, inflammatory cyto-kines, hemolysis, oxidase stress, and nephrotoxic agents, which result in tubular and vascular cell dysfunction, necrosis, apoptosis, and inflammation.[17,18] Even a minimal increase in serum Cr levels postoperatively is independently associated with long-term mortality and cardiovascular outcomes,[19] and might also contribute to chronic kidney dysfunction.[20] In 2012, the CORONARY trial that compared the 30-day outcome between on-pump surgery and off-pump surgery revealed an increased incidence of stage 1 and stage 2 AKI, but not stage 3 AKI and dialysis.[21] One-year follow-up analysis did not reveal substantial differences in loss of kidney function between the 2 groups.[22] Two explanations may be offered for this finding. First, the magnitude of AKI occurring after off-pump CABG might be related to prerenal azotemia without kidney structural damage. Second, revascularization might serve as a competing factor for the long-term renal

Table 2

Data for different surgical methods.

Variable	On-pump arrest (n=98)	On-pump beating (n=160)	Off-pump (n=115)	P
Left main coronary vessel	49 (50.0)	77 (48.1)	53 (46.1)	.848
Redo operation	2 (2.0)	1 (0.6)	2 (1.7)	.613
LIMA usage	90 (91.8)	149 (93.1)	105 (91.3)	.855
Emergent/urgent operation	17 (17.3)	47 (29.4)	31 (27.0)	.081
Mean number of bypassed grafts	3.2±0.7	3.1±0.7	2.8±0.9	<.001
Lowest Hb during CPB, g/dL	7.1±1.4	7.7±1.4	9.7±1.5	<.001
Blood transfusion unit, pack	9.1±6.4	7.2±6.3	3.6±4.2	<.001
Aortic cross-clamping time, minutes	90.1±33.3	NA	NA	NA
Cardiopulmonary bypass time, minutes	133.5±60.3	110.6±40.3	NA	NA

CPB = cardiopulmonary bypass, Hb = hemoglobin, LIMA = left internal mammary artery, NA = not applicable.

Table 3

Comparison of incidence of in-hospital death among surgical methods using subclassification analysis of propensity score.

	On-pump arrest		On-pump beating		Arrest vs beating	
Comparison/quintile	n	Event (%)	n	Event (%)	Odds ratio (95% CI)	P
On-pump arrest vs on-pump beating						
First quintile	28	1 (3.6)	23	3 (13.0)	0.25 (0.02, 2.55)	.241
Second quintile	24	1 (4.2)	28	1 (3.6)	1.17 (0.07, 19.83)	.912
Third quintile	21	1 (4.8)	31	2 (6.5)	0.73 (0.06, 8.55)	.798
Fourth quintile	15	1 (6.7)	37	5 (13.5)	0.46 (0.05, 4.28)	.493
Fifth quintile	10	3 (30.0)	41	5 (12.2)	3.09 (0.60, 15.98)	.179
Combined	**98**	**7 (7.1)**	**160**	**16 (10.0)**	**0.86 (0.33, 2.25)**[*]	**.762**

	On-pump arrest		Off-pump		Arrest vs off-pump	
Comparison/quintile	n	Event (%)	n	Event (%)	Odds ratio (95% CI)	P
On-pump arrest versus off-pump						
First quintile	28	4 (14.3)	14	2 (14.3)	1.00 (0.16, 6.26)	1.000
Second quintile	22	0 (0.0)	21	1 (4.8)	NA	NA
Third quintile	19	1 (5.3)	24	2 (8.3)	0.61 (0.05, 7.30)	.697
Fourth quintile	18	0 (0.0)	25	0 (0.0)	NA	NA
Fifth quintile	11	2 (18.2)	31	2 (6.5)	3.22 (0.40, 26.26)	.274
Combined	**98**	**7 (7.1)**	**115**	**7 (6.1)**	**1.04 (0.33, 3.33)**[*]	**.946**

	On-pump beating		Off-pump		Beating vs off-pump	
Comparison/quintile	n	Event (%)	n	Event (%)	Odds ratio (95% CI)	P
On-pump beating vs off-pump						
First quintile	43	8 (18.6)	12	2 (16.7)	1.14 (0.21, 6.27)	.878
Second quintile	36	4 (11.1)	19	2 (10.5)	1.06 (0.18, 6.41)	.947
Third quintile	25	1 (4.0)	30	2 (6.7)	0.58 (0.05, 6.84)	.668
Fourth quintile	31	3 (9.7)	24	1 (4.2)	2.46 (0.24, 25.31)	.448
Fifth quintile	25	0 (0.0)	30	0 (0.0)	NA	NA
Combined	**160**	**16 (10.0)**	**115**	**7 (6.1)**	**1.16 (0.44, 3.04)**[*]	**.759**

CI = confidence interval, NA = not applicable. Bold value signifies statistically significant.
[*] The combined odds ratio was estimated using the quintile of propensity score as a stratum variable in the logistic regression model.

Table 4

Comparison of incidence of acute kidney injury among surgical methods using subclassification analysis of propensity score.

	On-pump arrest		On-pump beating		Arrest vs beating	
Comparison/quintile	n	Event (%)	n	Event (%)	Odds ratio (95% CI)	P
On-pump arrest vs on-pump beating						
First quintile	28	10 (35.7)	23	5 (21.7)	2.00 (0.57, 7.03)	.280
Second quintile	24	7 (29.2)	28	6 (21.4)	1.51 (0.43, 5.33)	.522
Third quintile	21	7 (33.3)	31	8 (25.8)	1.44 (0.43, 4.83)	.558
Fourth quintile	15	5 (33.3)	37	10 (27.0)	1.35 (0.37, 4.93)	.650
Fifth quintile	10	5 (50.0)	41	18 (43.9)	1.28 (0.32, 5.10)	.729
Combined	**98**	**34 (34.7)**	**160**	**47 (29.4)**	**1.50 (0.85, 2.63)**[*]	**.162**

	On-pump arrest		Off-pump		Arrest vs off-pump	
Comparison/quintile	n	Event (%)	n	Event (%)	Odds ratio (95% CI)	P
On-pump arrest vs off-pump						
First quintile	28	12 (42.9)	14	4 (28.6)	1.88 (0.47, 7.45)	.372
Second quintile	22	6 (27.3)	21	4 (19.0)	1.59 (0.38, 6.71)	.525
Third quintile	19	7 (36.8)	24	5 (20.8)	2.22 (0.57, 8.60)	.250
Fourth quintile	18	6 (33.3)	25	0 (0.0)	NA	NA
Fifth quintile	11	3 (27.3)	31	4 (12.9)	2.53 (0.47, 13.75)	.282
Combined	**98**	**34 (34.7)**	**115**	**17 (14.8)**	**2.67 (1.35, 5.26)**[*]	**.005**

	On-pump beating		Off-pump		Beating vs off-pump	
Comparison/quintile	n	Event (%)	n	Event (%)	Odds ratio (95% CI)	P
On-pump beating vs off-pump						
First quintile	43	18 (41.9)	12	4 (33.3)	1.44 (0.38, 5.52)	.595
Second quintile	36	13 (36.1)	19	7 (36.8)	0.97 (0.31, 3.07)	.957
Third quintile	25	8 (32.0)	30	2 (6.7)	6.59 (1.25, 34.74)	.026
Fourth quintile	31	4 (12.9)	24	4 (16.7)	0.74 (0.17, 3.33)	.695
Fifth quintile	25	4 (16.0)	30	0 (0.0)	NA	NA
Combined	**160**	**47 (29.4)**	**115**	**17 (14.8)**	**1.83 (0.96, 3.50)**[*]	**.066**

CI = confidence interval, NA = not applicable. Bold value signifies statistically significant.
[*] The combined odds ratio was estimated using the quintile of propensity score as a stratum variable in the logistic regression model.

Table 5

Comparison of incidence of hemodialysis among surgical methods using subclassification analysis of propensity score.

Comparison/quintile	On-pump arrest		On-pump beating		Arrest vs beating	
	n	Event (%)	n	Event (%)	Odds ratio (95% CI)	P
On-pump arrest vs on-pump beating						
First quintile	28	1 (3.6)	23	1 (4.3)	0.82 (0.05, 13.79)	.887
Second quintile	24	0 (0.0)	28	1 (3.6)	NA	NA
Third quintile	21	1 (4.8)	31	1 (3.2)	1.50 (0.09, 25.39)	.779
Fourth quintile	15	1 (6.7)	37	4 (10.8)	0.59 (0.06, 5.75)	.649
Fifth quintile	10	1 (10.0)	41	1 (2.4)	4.44 (0.25, 77.96)	.307
Combined	**98**	**4 (4.1)**	**160**	**8 (5.0)**	**0.92 (0.26, 3.25)**[*]	**.898**

Comparison/quintile	On-pump arrest		Off-pump		Arrest vs off-pump	
	n	Event (%)	n	Event (%)	Odds ratio (95% CI)	P
On-pump arrest vs off-pump						
First quintile	28	2 (7.1)	14	1 (7.1)	1.00 (0.08, 12.07)	1.000
Second quintile	22	1 (4.5)	21	0 (0.0)	NA	NA
Third quintile	19	0 (0.0)	24	2 (8.3)	NA	NA
Fourth quintile	18	1 (5.6)	25	0 (0.0)	NA	NA
Fifth quintile	11	0 (0.0)	31	2 (6.5)	NA	NA
Combined	**98**	**4 (4.1)**	**115**	**5 (4.3)**	**0.84 (0.21, 3.41)**[*]	**.811**

Comparison/quintile	On-pump beating		Off-pump		Beating vs off-pump	
	n	Event (%)	n	Event (%)	Odds ratio (95% CI)	P
On-pump beating vs off-pump						
First quintile	43	4 (9.3)	12	1 (8.3)	1.13 (0.11, 11.15)	.918
Second quintile	36	3 (8.3)	19	4 (21.1)	0.34 (0.07, 1.72)	.192
Third quintile	25	1 (4.0)	30	0 (0.0)	NA	NA
Fourth quintile	31	0 (0.0)	24	0 (0.0)	NA	NA
Fifth quintile	25	0 (0.0)	30	0 (0.0)	NA	NA
Combined	**160**	**8 (5.0)**	**115**	**5 (4.3)**	**0.69 (0.21, 2.30)**[*]	**.547**

CI = confidence interval, NA = not applicable. Bold value signifies statistically significant.

[*] The combined odds ratio was estimated using the quintile of propensity score as a stratum variable in the logistic regression model.

outcome, whereas incomplete and suboptimal revascularization might be related to technical difficulties in long-term follow-up.[23] Reduction of cardiopulmonary bypass duration also attenuates pump-induced hemolysis, thereby releasing hemoglobin and free iron, and injuring the renal tubule.[24] Large-scale hemodilution and more blood transfusion during on-pump beating surgery might reduce oxygen delivery and induce inflammation through blood transfusion.[25,26] Although off-pump CABG might reduce

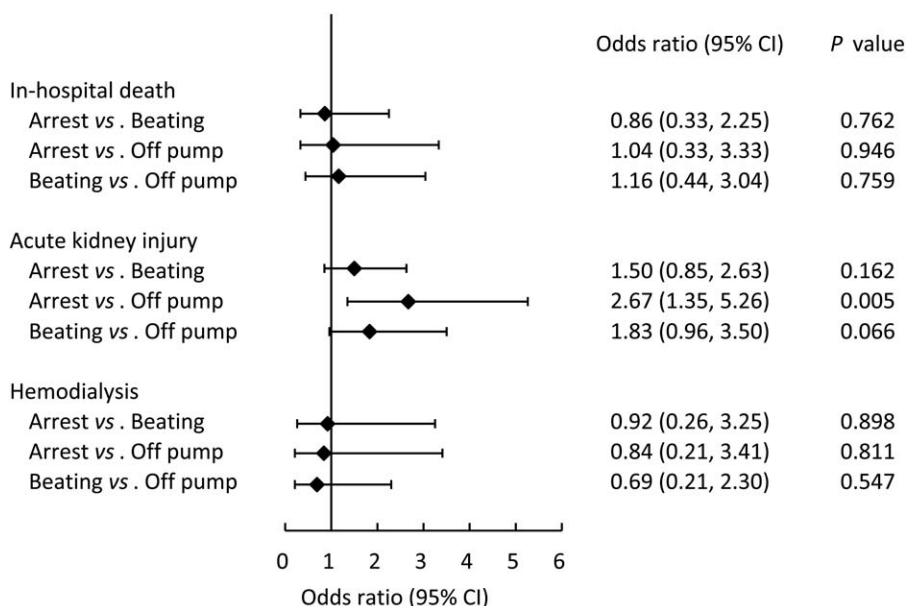|	Odds ratio (95% CI)	P value
In-hospital death		
Arrest vs. Beating	0.86 (0.33, 2.25)	0.762
Arrest vs. Off pump	1.04 (0.33, 3.33)	0.946
Beating vs. Off pump	1.16 (0.44, 3.04)	0.759
Acute kidney injury		
Arrest vs. Beating	1.50 (0.85, 2.63)	0.162
Arrest vs. Off pump	2.67 (1.35, 5.26)	0.005
Beating vs. Off pump	1.83 (0.96, 3.50)	0.066
Hemodialysis		
Arrest vs. Beating	0.92 (0.26, 3.25)	0.898
Arrest vs. Off pump	0.84 (0.21, 3.41)	0.811
Beating vs. Off pump	0.69 (0.21, 2.30)	0.547

Figure 1. Comparison of incidence of categorical outcome among surgical methods. The combined odds ratio was estimated using the quintile of propensity score as a stratum variable in the logistic regression model.
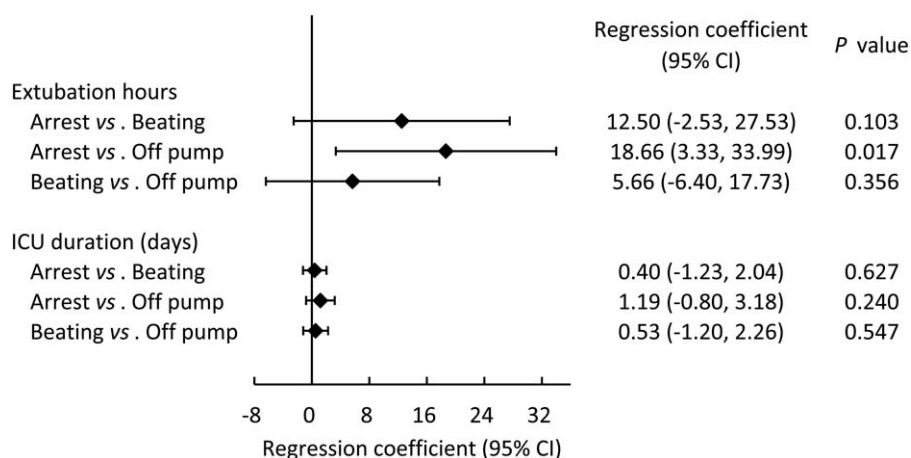
Figure 2. Comparison of continuous outcome among surgical methods. The combined regression coefficient was estimated using the linear mixed-effect model using the quintile of propensity score as a clustered variable.

the physiologic derangement caused by the systemic inflammatory response and attenuate the myocardial injury caused by ischemia–reperfusion, the on-pump method provides improved long-term survival, because of the patency of the anastomosis of blood vessels.[27]

In the past decade, a hybrid method (ie, OPBH surgery) combining standard on-pump surgery and the off-pump CABG technique has been used to avoid cardioplegic arrest and its nonphysiological nature, which may lead to mortality and morbidity in patients with poor cardiac function. The absence of cardioplegic arrest and hemodynamic stability are the highest benefits of this technique, particularly for patients with left ventricular dysfunction.[13,28,29] We hypothesized that OPBH surgery would provide improved systemic circulation and influence the renal outcome.[30] Chaudhry et al and Ueki et al, respectively, performed a good meta-analysis to compare the results between OPBH and conventional arrest CABG, both of them concluded that dialysis-requiring renal failure was less in OPBH-CABG. [31–33] There are no data regarding AKI by KDIGO definition in meta-analysis. In our result, dialysis seems to be less in OPBH, tough it did not reach statistical significance using propensity score analysis. In this study, we directly compared the short-term survival and renal outcomes among the OPBH, no-pump arrest, and off-pump CABG groups through propensity analysis. Regarding AKI incidence, off-pump surgery is superior to on-pump arrest, but not dialysis; this result is similar to that of a meta-analysis.[34] No substantial difference was observed in mortality, AKI, and RRT between the OPBH and off-pump groups. The avoidance of systemic hypothermia, cardiac arrest, rewarming, and recovery from myocardial stunning theoretically maintained the stability of systemic circulation and might facilitate the reduction of renal ischemia. This study provides evidence that in patients with a high surgical risk, the short-term outcomes, including mortality and renal dysfunction, of the OPBH method, are not inferior to those of off-pump surgery. Further comparisons of long-term outcomes would be valuable.

4.1. Study limitations

Despite the favorable results, several limitations should be noted. First, compared with other large-scale trials, our investigation was based on a small number of risky patients and was conducted at a single tertiary care medical center in Asia; therefore, regional and ethnic differences should be considered. Second, because postoperative care, postoperative bleeding, and infection contribute to AKI, researchers who aspire to expand the application to AKI occurring after postoperative day 7 should exercise caution. Finally, though all surgeons in this study were familiar with these surgical techniques, a selection bias that is caused by surgeon preference still might exist. Additional randomized trials are warranted to eliminate this limitation.

5. Conclusions

This study is the first to directly compare the incidence of AKI among the 3 surgical types. The on-pump arrest CABG method results in a higher incidence of AKI, which contributes to a lower incidence of mild and moderate AKI when compared with conventional CABG. In patients with a high surgical risk, the OPBH method is a reasonable choice.

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