International Journal of Integrated Health Sciences (IIJHS)
ISSN Print: 2302-1381; ISSN Online: 2338-4506

Original Article

In-Hospital Outcomes Comparison Between Off-Pump and On-Pump CABG: Indonesian Tertiary Center Experience

Triwedya Indra Dewi,[1] Ridho Jungjunan,[1] Pradana Pratomo Raharjo,[1] Aliya Rahmadewi Rezkita,[1] Syarief Hidayat,[1] Januar Wibawa Martha,[1] Rama Nusjirwan,[2] Mohammad Rizki Akbar[1]

[1]Department of Cardiology and Vascular Medicine, Faculty of Medicine Universitas Padjadjaran-Dr. Hasan Sadikin General Hospital, Bandung, Indonesia
[2]Division of Cardio-Thoracic and Vascular Surgery, Department of Surgery, Faculty of Medicine Universitas Padjadjaran-Dr. Hasan Sadikin General Hospital, Bandung, Indonesia

Article History

Received: September 25, 2024
Accepted: September 30, 2025
Published: October 30, 20255

DOI: 10.15850/ijihs.v13n2.4119
IJIHS. 2025;13(2):96–104

Correspondence:
Pradana Pratomo Raharjo, Department of Cardiology and Vascular Medicine, Faculty of Medicine Universitas Padjadjaran-Dr. Hasan Sadikin General Hospital, Bandung, Indonesia
Email:pradana.p.r@gmail.com

Abstract

Background: Coronary artery disease (CAD) often requires revascularization. Coronary artery bypass grafting (CABG) is a cornerstone intervention that improves patients' survival. Both on-pump and off-pump CABG have their own advantages and limitations, with reported outcomes vary across studies.

Objective: to investigate the differences in the outcomes of patients undergoing off-pump and on-pump CABG.

Methods: A retrospective cohort study was performed on 186 patients aged ≥18 years undergoing on-pump or off-pump CABG between June 2020 and December 2023. Outcomes included were all-cause mortality, postoperative acute renal failure, length of postoperative stay, and complete revascularization rate. Comparative analysis was conducted using Chi-Square test and independent T-test. Multivariate analysis, including logistic regression tests, was carried out to identify independent predictors associated with each outcome.

Results: The on-pump group presented more diabetes (42.9% vs. 28.4%; p=0.040) and lower left ventricular ejection fraction (LVEF) values (43 [IQR 16–79] vs. 53 [23–75]; p=0.001). Patients in this group also had higher rates of postoperative renal failure (61.5% vs. 24.2%; p<0.001), longer stays (64.8% vs. 41.1%; p=0.001), and better complete revascularization (98.9% vs. 92.6%; p=0.035), but no significant difference in mortality (16.5% vs. 13.7%; p =0.594). Multivariate analysis identified diabetes, LVEF ≤40%, and postoperative renal failure as predictors of mortality.

Conclusions: On-pump CABG is associated with higher rates of complete revascularization. However, the adoption of this technique is linked to a higher risk of postoperative acute kidney failure and prolonged hospital stays. No difference in mortality is observed between those with off-pump and on-pump.

Keywords: Coronary artery bypass surgery, coronary artery disease, off-pump, on-pump, revascularization

Introduction

Coronary artery disease (CAD) is a prevalent condition characterized by the narrowing of coronary arteries, leading to inadequate oxygen supply to the heart. In cases where medical management fails to alleviate symptoms, cardiac catheterization has been reported to provide valuable anatomical insights, aiding clinicians in deciding between percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG).[1] Several studies have shown that CABG is a cornerstone intervention, improving both

survival and quality of life in patients with CAD.[2]

CABG can be performed using either on-pump or off-pump techniques. On-pump comprises the use of cardiopulmonary bypass (CPB) and cardioplegic arrest, which can trigger inflammatory responses and global myocardial ischemia, increasing postoperative morbidity and mortality. Meanwhile, off-pump is a more recent technique, which can prevent these drawbacks by avoiding CPB and cardioplegic arrest. During the procedure, the surgeon stabilizes the area around the occluded coronary artery while grafting blood vessels onto the beating heart, leading to reduced inflammation and morbidity. Several studies have compared the efficacy of off-pump and on-pump CABG techniques, yielding variable results.[3] Therefore, this study aimed to assess and compare the treatment outcomes between off-pump and on-pump CABG procedures in CAD patients at a tertiary hospital in Indonesia.

Methods

This retrospective cohort study analyzed patients diagnosed with CAD who underwent CABG procedures, either using on-pump or off-pump techniques, at Hasan Sadikin Hospital, Bandung, Indonesia, from June 2020 to December 2023. Patient data were retrieved from their medical records and registries. The ethical clearance code was DP.04.03/D.XIV.6.5/135/2024. Inclusion criteria comprised individuals aged ≥18 years with a clinical indication for CABG and documented left ventricular ejection fraction (LVEF) values calculated using Simpson's biplane method. Exclusion criteria included patients with a history of alternative cardiac conditions necessitating procedures other than CABG, those subjected to intraoperative conversion from off-pump to on-pump CABG surgery, and those possessing incomplete medical records.

Patient data consisted of demographic characteristics, comorbidity history, and baseline LVEF measurements. The study examined several results, including all-cause mortality, postoperative acute renal failure, length of stay (LOS) following surgery, and the rate of complete revascularization. Mortality included fatalities attributed to all causes, comprising both cardiovascular and non-cardiovascular etiologies, which occurred during the hospitalization period. Postoperative acute renal failure was defined as an elevation in serum creatinine of 0.3 mg/dl (≥26.5 mol/l) from baseline within 48 hours after surgery or a reduction in urine output to less than 0.5 ml/kg/hour for 6 hours. Prolonged LOS was identified as a stay exceeding 7 days.

In this study, numerical data were presented as either mean and standard deviation or median and range, contingent upon the normality distribution of the data. Furthermore, categorical data were expressed as counts and percentages. Comparative analysis used the independent T-test for normally distributed data and the Mann-Whitney test as an alternative. The Chi-Square test was applied to compare categorical variables across groups. Subsequently, multivariate analysis was conducted using logistic regression to identify independent predictors of patient survival. The determination of independent predictor factors relied on the risk ratio (RR) and 95% confidence interval (CI). A p-value of ≤0.05 revealed statistical significance, which was performed using SPSS version 25.0 for Windows and STATA software.

Results

A total of 186 CAD patients were included: 91 underwent on-pump CABG and 95 underwent off-pump CABG. Most participants (84.9%) were male, with a mean age of 58±9 years. Diabetes mellitus was more prevalent in the on-pump group than in the off-pump group (42.9% vs. 28.4%; p=0.040). Furthermore, the on-pump group demonstrated a lower median LVEF than the off-pump group (43 [IQR 16–79] vs. 53 [23–75]; p=0.001). These baseline imbalances—particularly the higher prevalence of diabetes and lower LVEF—are clinically relevant, as they may affect postoperative outcomes. Other characteristics were comparable between groups (Table 1).

The on-pump cohort exhibited significantly higher rates of postoperative acute renal failure compared with the off-pump cohort (61.5% vs. 24.2%; p<0.001), highlighting the renal burden associated with CPB. Additionally, the on-pump group had prolonged LOS (64.8% vs. 41.1%; p=0.001) and higher complete revascularization rates (98.9% vs. 92.6%; p=0.035). However, no significant differences were observed in mortality rates between the 2 groups (16.5% vs. 13.7%; p=0.594). While mortality was comparable, the marked differences in renal outcomes, length of stay, and completeness of revascularization highlight important trade-offs between the two surgical techniques.The

Table 1 Baseline Characteristics of the Study Population

Characteristics	Total (n=186)	CABG Techniques		p-value
		On-pump (n=91)	Off-pump (n=95)	
Age (years), mean±SD	58±9	57±8	58±9	0.563[a]
Age groups, n (%)				
≥70 years	10 (5.4)	3 (3.3)	7 (7.4)	0.331[d]
<70 years	176 (94.6)	88 (96.7)	88 (92.6)	
Male, n (%)	158 (84.9)	76 (83.5)	82 (86.3)	0.594[c]
Comorbidities, n (%)				
Hypertension	115 (61.8)	58 (63.7)	57 (60.0)	0.600[c]
Diabetes mellitus	66 (35.5)	39 (42.9)	27 (28.4)	0.040[c]*
Stroke	23 (12.4)	14 (15.4)	9 (9.5)	0.221[c]
Acute coronary syndrome	41 (22)	19 (20.9)	22 (23.2)	0.708[c]
Leukocytosis	16 (8.6)	9 (9.9)	7 (7.4)	0.540[c]
Anemia	49 (26.3)	27 (29.7)	22 (23.2)	0.313[c]
Renal dysfunction	44 (23.7)	26 (28.6)	18 (18.9)	0.123[c]
LVEF (%), median (IQR)	48 (16 – 79)	43 (16 – 79)	53 (23 – 75)	0.001[b]*
LVEF groups, n (%)				
≤40%	63 (33.9)	38 (41.8)	25 (26.3)	0.026[c]*
>40%	123 (66.1)	53 (58.2)	53 (58.2)	

Note: The p-value used paired t-test[a], Mann-Whitney test[b], Chi-Square test[c], and Fisher Exact test[d], *significant when p<0.05

detailed outcomes are presented in Table 2. To further explore factors influencing mortality, subgroup and multivariate analyses were subsequently performed.

When comparing the group of patients who succumbed to those who survived, a higher prevalence of LVEF values ≤40% (57.1% vs. 29.7%; p=0.005) and postoperative acute renal failure (75.0% vs. 36.7%; P<0.001) was observed among the deceased (Table 3). Multivariate analysis identified diabetes mellitus (RR 1.034; 95% CI= 1.034–1.034; p<0.001), LVEF ≤40% (RR 1.964; 95% CI 1.115 – 3.457; p=0.019), and postoperative acute renal failure (RR 4.815; 95% CI: 2.253 –10.289; p<0.001) as independent predictors of patient mortality. Meanwhile, the choice of the CABG technique was not predictive

Table 2 Outcome Differences Between CABG Techniques

Outcome	Total (n=186)	CABG Techniques		p-value
		On-pump (n=91)	Off-pump (n=95)	
In-hospital mortality, n (%)	28 (15.1)	15 (16.5)	13 (13.7)	0.594
Postoperative acute renal failure, n (%)	79 (42.5)	56 (61.5)	23 (24.2)	<0.001*
Prolonged length of stay, n (%)	98 (52.7)	59 (64.8)	39 (41.1)	0.001*
Complete revascularization, n (%)	178 (95.7)	90 (98.9)	88 (92.6)	0.035*

Note: The p-value used the Chi-Square test, *significant when p<0.05

Table 3 Differences in Participants Characteristics Between the Survived and Deceased Groups

Characteristics	Outcomes		p-value
	Deceased n=28	Survived n=158	
Age groups, n (%)			
≥70 years	0 (0)	10 (6.3)	0.364
<70 years	28 (100)	148 (93.7)	
Male, n (%)	25 (89.3)	133 (84.2)	0.486
Comorbidities, n (%)			
Hypertension	16 (57.1)	99 (62.7)	0.580
Diabetes mellitus	12 (42.9)	54 (34.2)	0.376
Stroke	4 (14.3)	19 (12)	0.756
Acute coronary syndrome	8 (28.6)	33 (20.9)	0.366
Leukocytosis	2 (7.1)	14 (8.9)	1.000
Anemia	9 (32.1)	40 (25.3)	0.450
Renal dysfunction	9 (32.1)	35 (22.2)	0.252
LVEF groups, n (%)			
≤40%	16 (57.1)	47 (29.7)	0.005*
>40%	12 (42.9)	111 (70.3)	
Postoperative acute renal failure, n (%)	21 (75)	58 (36.7)	<0.001*
Complete revascularization, n (%)	27 (96.4)	151 (95.6)	1.000

Note: The p-value used the Chi-Square test, *significant when p<0.05

Table 4 Mortality Rate Across Different Clinical Groups

Group	Person-time	Deaths	Mortality Rate (per 100 person-days)
Overall	1,568	28	1.8 (95% CI: 1.2–2.6)
Procedure technique			
On-pump	863	15	1.7 (95% CI: 1.0–2.9)
Off-pump	705	13	1.8 (95% CI: 1.1–3.2)
Diabetes mellitus			
Yes	570	12	2.1 (95% CI: 1.2–3.7)
No	998	16	1.6 (95% CI: 1.0–2.6)
LVEF group,			
≤40%	499	16	3.2 (95% CI: 1.9–5.2)
>40%	1069	12	1.1 (95% CI: 0.6–2.0)
Postoperative acute renal failure			
Yes	762	21	2.8 (95% CI: 1.8–4.2)
No	806	7	0.9 (95% CI: 0.4–1.8)

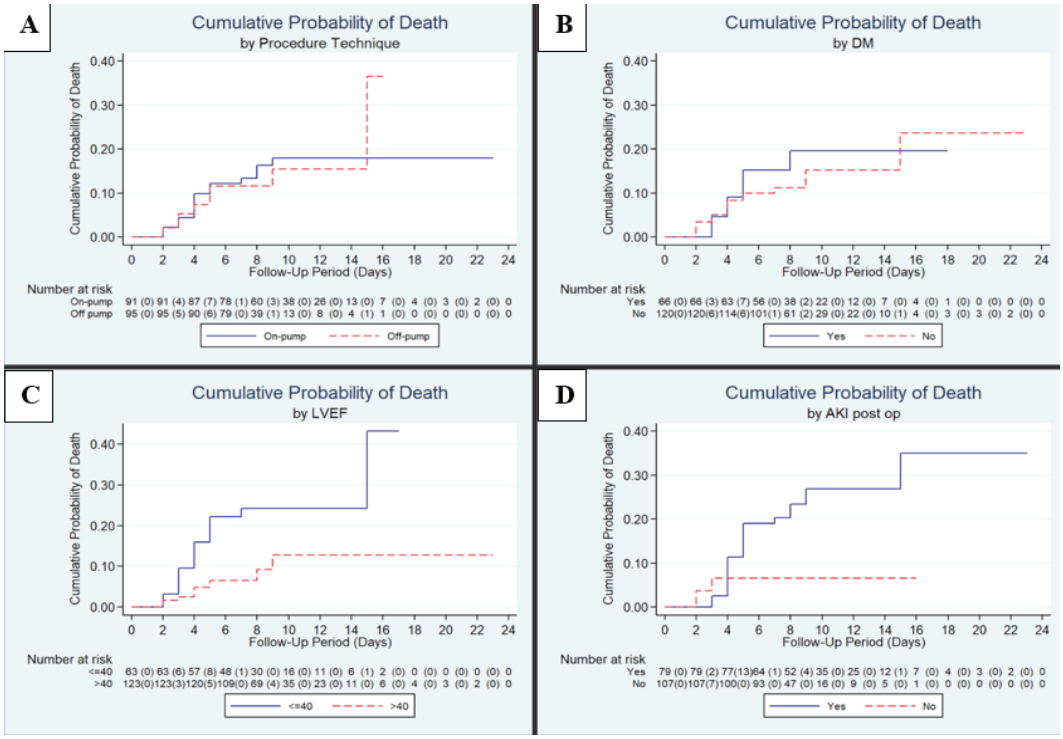

Fig. 1 Mortality rate based on: (A) CABG technique; (B) presence of DM; (C) LVEF value; (D) presence of postoperative acute renal failure

of mortality. These findings suggest that patient comorbidities and postoperative complications may be stronger determinants of in-hospital mortality than the surgical technique itself. Consistent with this, no significant disparity in mortality rates was observed between the on-pump and off-pump groups (1.7 [1.0–2.9] vs. 1.8 [1.1–3.2] per 100 person-days) as presented in Table 4 and Fig 1.

Regarding the outcome of postoperative acute renal failure, the on-pump surgical technique emerged as the sole independent predictor (RR 2.309; 95% CI 1.557–3.425; p<0.001). Similarly, the on-pump technique was the lone significant independent predictor of prolonged LOS (RR 1.607; 95% CI 1.209 – 2.137; p=0.001). As for the outcome of complete revascularization, independent predictors comprised the use of the on-pump technique (RR 1.061; 95% CI 1.061 – 1.061; P<0.001), presence of diabetes mellitus (RR 0.924; 95% CI 0.924–0.924; p<0.001), and LVEF ≤40% (RR 0.969; 95% CI 0.969–0.969; p<0.001) as shown in Table 5.

Discussion

This study marked the inaugural comparison of outcomes between CAD patients undergoing on-pump and off-pump CABG procedures at the institution. Findings from this investigation revealed that while on-pump CABG correlated with heightened rates of complete revascularization, it was also related to an increased likelihood of postoperative acute renal injury and prolonged length of hospital stay in contrast to off-pump CABG. Notably, no significant differences in mortality rates were observed between the 2 groups.

Demographically, the majority of participants in this study were male, consistent with findings from several previous investigations. This male predominance among CABG recipients could be attributed to the onset of cardiovascular disease typically occurring at an older age in women. Therefore, this augmented surgical risk and potentially influenced the adoption of less aggressive treatment approaches in this demographic. [4] [5] Hypertension remained the most common comorbidity in this cohort. Chua *et al*.

Table 5 Multivariate Analysis of Factors Associated With In-Hospital Outcomes

Variables	B	SE	p-value	RR (95% CI)
Outcome: In-hospital mortality				
On-pump CABG	0.081	0.539	0.063	1.554 (0.977 – 2.470)
Diabetes mellitus	0.230	0.510	<0.001*	1.034 (1.034 – 1.034)
LVEF ≤40%	0.748	0.496	0.019*	1.964 (1.115 – 3.457)
Postoperative acute renal failure	2.358	0.563	<0.001*	4.815 (2.253 – 10.289)
Outcome: Postoperative acute renal failure				
On-pump CABG	1.498	0.331	<0.001*	2.309 (1.557 – 3.425)
Diabetes mellitus	0.284	0.343	0.308	0.861 (0.646 – 1.148)
Renal dysfunction	0.701	0.384	0.082	1.292 (0.968 – 1.724)
LVEF ≤40%	0.435	0.345	0.351	1.147 (0.860 – 1.529)
Outcome: Prolonged LOS				
On-pump CABG	1.154	0.327	0.001*	1.607 (1.209 – 2.137)
Diabetes mellitus	0.301	0.332	0.737	0.956 (0.737 – 1.241)
LVEF ≤40%	-0.730	0.342	0.103	0.784 (0.585 – 1.051)
Outcome: Complete revascularization				
On-pump CABG	1.785	1.097	<0.001*	1.061 (1.061 – 1.061)
Age ≥70 years	-1.993	0.991	0.174	0.810 (0.597 – 1.098)
Diabetes mellitus	1.380	1.123	<0.001*	0.924 (0.924 – 0.924)
LVEF ≤40%	-0.158	0.894	<0.001*	0.969 (0.969 – 0.969)

Note: B: regression coefficient; SE: standard error; RR: risk ratio; CI: confidence interval; *significant when p<0.05

conducted a comparable investigation, which indicated that hypertension was the second most prevalent comorbidity, with a prevalence of 75.4%, following dyslipidemia at 82.8%. Based on univariate Cox analysis, hypertension was also identified as a significant risk factor associated with post-CABG mortality,ith a hazard ratio of 1.79 (95% CI: 1.50–2.12) and a p-value of <0.001.[6]

Diabetes mellitus was more prevalent in the on-pump group and emerged as an independent predictor of mortality, consistent with previous studies such as Pezeshki *et al*., which demonstrated a significantly increased long-term mortality risk in diabetic patients after CABG.[7] This reinforces the importance of diabetes as a critical comorbidity influencing surgical outcomes. Patients undergoing on-pump CABG also had lower baseline LVEF and a higher proportion with LVEF ≤40%. Consistent with previous reports, very low LVEF (<35%) is often considered a relative contraindication to off-pump CABG, although some studies suggest it remains feasible in selected high-risk patient.[8,9]

In terms of patient outcomes, the overall mortality rate observed in this study was 15.1%, with a mortality rate of 1.8 per 100 person-days. This surpassed previous reports from Nomali *et al.*, which indicated that in-hospital mortality occurred in 2.8% (n=103) of the patients.[10] Differences in baseline risk profiles likely contributed to this discrepancy, particularly the higher prevalence of reduced LVEF in our cohort (33.9%), compared with 17.2% in the ROOBY trial (LVEF <45%) and 5.7% with LVEF <35%.[11] The higher mortality observed in our cohort may also reflect the absence of factors highlighted by Awan *et al*., such as advances in surgical techniques, improved cardiac anesthesia, optimized postoperative care, and the availability of mechanical circulatory support including ECMO and LVAD.[4]

On-pump CABG procedures using CPB and cardioplegic arrest theoretically posed

a risk of eliciting inflammatory responses and global myocardial ischemia, potentially leading to increased postoperative morbidity and mortality. Nevertheless, in our cohort, the choice of surgical technique did not significantly influence early mortality, as confirmed by multivariate analysis. This is consistent with contemporary evidence suggesting that surgical technique alone is insufficient to determine early mortality without considering the broader clinical context. For instance, Marin-Cuartas *et al*. observed no difference in short-term mortality between off-pump and on-pump CABG in patients with severe LV dysfunction, while Rösler *et al*. similarly found no significant difference in 30-day mortality.[13]

The comparison of outcomes between on-pump and off-pump CABG was a subject of debate, yielding mixed findings across studies. While some investigations were consistent with the present outcomes, others reported different results. For example, Rao *et al*. demonstrated significantly lower 30-day mortality in patients undergoing off-pump CABG compared with on-pump procedures. By contrast, in our cohort, no significant difference was observed, which may reflect both the limited sample size and the high-risk profile of patients in both groups. Furthermore, variations in results across studies were influenced by disparities between participating centers, including variations in operator proficiency levels and the annual caseload volume at these centers.[15] This suggests that the elevated baseline risk in our population may have exerted a greater influence on early mortality than the choice of surgical technique itself.

Patients with LVEF ≤40% exhibited higher mortality than those with LVEF >40%, and multivariate analysis confirmed impaired LVEF as an independent predictor of mortality. These findings are consistent with Awan *et al*., who likewise reported significantly higher mortality in patients with reduced LVEF.[4] In line with these findings, our results emphasize that impaired left ventricular function represents a crucial determinant of short-term survival following CABG. Furthermore, Caputti *et al*. highlighted that in a specific subgroup of patients with severe LV dysfunction, off-pump techniques could confer a reduced risk of mortality compared to on-pump techniques.[16]

Patients experiencing postoperative acute renal failure demonstrated a higher mortality rate compared to those without this complication. In line with previous findings, our study further highlights that acute renal failure is not only a common complication but also a critical determinant of short-term mortality after CABG. Bell *et al*. similarly reported substantially increased 90-day mortality in patients with postoperative renal failure, while Zakkar *et al*. found reduced long-term survival in those with AKI undergoing redo CABG.[18.] Aditionally, Palamuthusingam *et al*., in a meta-analysis involving 15 studies and 11,000 patients undergoing heart surgery, reported a fourfold higher risk of mortality among patients experiencing postoperative acute renal failure.[19] These observations underscore the importance of early identification, preventive strategies, and aggressive perioperative management of renal dysfunction in CABG patients to improve outcomes. Wang *et al*. similarly observed a reduced risk of postoperative new renal insufficiency among patients undergoing off-pump compared to those undergoing on-pump CABG.[20] Multivariate analysis further affirmed the on-pump technique as an independent predictor of this complication, which potentially attributed to the inflammatory effects and use of CPB.[2] Consistent with these findings, this study revealed a significant difference in the proportion of patients experiencing postoperative acute renal failure between the 2 groups, with a higher incidence observed in the on-pump group compared to the off-pump group. This suggests that patient selection and perioperative renal protection may be particularly critical in those requiring on-pump CABG.

This study identified a higher prevalence of prolonged LOS in the on-pump group compared to the off-pump group. Multivariate analysis confirmed the on-pump technique as an independent predictor of prolonged hospitalization . A study by Caputti *et al*. similarly reported a reduction in LOS among patients with severe LV dysfunction undergoing off-pump compared to on-pump CABG. Consistent with these observations, Khan *et al*., in a meta-analysis involving 16 retrospective studies and 27.623 patients reported that length of hospital stay was significantly lower in the off-pump patients.[21] These results indicate that the use of CPB may contribute to longer hospitalization, which in turn has implications for both patient recovery and healthcare resource utilization.

The incidence of complete revascularization was higher in the on-pump CABG compared to the off-pump group, which was consistent with the results of multivariate analysis in this study. Previous studies have also reported

similar findings: Benedetto *et al*. and Chikwe *et al*. both demonstrated higher rates of incomplete revascularization in off-pump patients, which in turn were associated with worse long-term outcomes such as reduced survival and recurrent angina. This heightened rate of incomplete revascularization was linked to reduced survival rates and a higher incidence of recurrent angina in the long term[22,15]. However, this study focused on short-term outcomes and did not identify incomplete revascularization as an independent predictor of in-hospital mortality. Marin-Cuartas *et al*. similarly found a higher rate of incomplete revascularization in the off-pump CABG group but observed no difference in the 30-day post-admission mortality rate between the off-pump and on-pump groups.[12] This suggested that the potential benefits of off-pump CABG techniques could offset the disadvantages of incomplete revascularization, at least in the immediate postoperative period. From a clinical perspective, this emphasizes the need to balance the technical feasibility of achieving complete revascularization with the perioperative benefits of off-pump surgery, tailoring the approach to patient-specific risk profiles

This study had the potential to harbor several limitations. First, its retrospective and observational design without randomization introduces the potential for selection bias, as the choice of surgical technique may have been influenced by operator preference or resource availability. Second, the relatively modest sample size and single-center setting limit the statistical power and generalizability of our findings to broader populations. In addition, the on-pump and off-pump groups differed in certain baseline characteristics, such as the prevalence of diabetes and reduced LVEF, which could have affected the outcomes. The study also did not include STS SCORE or EUROSCORE data, thereby precluding stratification and outcome analysis of high-risk patients. Taken together, these issues indicate that the results should be interpreted with caution, and future prospective multicenter studies are warranted to validate these findings.

In conclusion, the choice of surgical technique should not be based solely on mortality outcomes. Although this study found no significant mortality difference between on-pump and off-pump CABG, important trade-offs were identified regarding renal outcomes, length of stay, and completeness of revascularization. Off-pump CABG may be preferred in patients at high risk of post operative acute renal failure, while on-pump CABG may be more appropriate for those requiring complete revascularization, particularly with complex coronary anatomy. Tailoring the operative approach to individual patient profiles is essential to optimize outcomes, and shared decision-making between clinicians and patients should be encouraged.

References

1. Shahjehan RD, Bhutta BS. Coronary artery disease. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan. Updated Oct 9, 2024. [cited 2023 Dec 25]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24811552
2. Khan MS, Islam MYU, Ahmed MU, Bawany FI, Khan A, Arshad MH. On-pump coronary artery bypass graft surgery versus off-pump coronary artery bypass graft surgery: a review. Glob J Health Sci. 2014;6(3):186–93. doi:10.5539/gjhs.v6n3p186
3. Sheikhy A, Fallahzadeh A, Forouzannia K, Pashang M, Tajdini M, Momtahen S, *et al*. Off-pump versus on-pump CABG outcomes in patients with severe LV dysfunction: inverse probability weighted study. BMC Cardiovasc Disord. 2022;22:295. doi:10.1186/s12872-022-02895-0
4. Awan NI, Jan A, Ur Rehman M, Ayaz N. Effect of ejection fraction on mortality in CABG patients. Pak J Med Sci. 2020;36(7):1454–9. doi:10.12669/pjms.36.7.3266
5. ten Haaf ME, Bax M, ten Berg JM, Brouwer J, van 't Hof AW, van der Schaaf RJ, *et al*. Sex differences in characteristics and outcome in ACS patients in the Netherlands. Neth Heart J. 2019;27(5):263–71. doi:10.1007/s12471-019-1271-0
6. Chua TKT, Gao F, Chia SY, Sin KYK, Naik MJ, Tan TE, *et al*. Long-term mortality after isolated CABG and risk factors for mortality. J Cardiothorac Surg. 2024;19:65. doi:10.1186/s13019-024-02943-0

7. Pezeshki PS, Masoudkabir F, Pashang M, Vasheghani-Farahani A, Jalali A, Sadeghian S, *et al*. Seven-year outcomes in diabetic patients after CABG in a developing country. BMC Cardiovasc Disord. 2023;23:279. doi:10.1186/s12872-023-03279-8
8. Verma S, Fedak PWM, Weisel RD, Szmitko PE, Badiwala MV, Bonneau D, *et al*. Off-pump CABG: fundamentals for the clinical cardiologist. Circulation. 2004;109(10):1206–11. doi:10.1161/01.CIR.0000120292.65143.F5
9. Li S, Gong W, Qi Q, Yuan Z, Chen A, Liu J, *et al*. Outcomes of off-pump versus on-pump CABG in patients with severely dilated LV. Ann Transl Med. 2016;4(18):361. doi:10.21037/atm.2016.08.49
10. Nomali M, Heidari ME, Ayati A, Moghaddam K, Mosallami S, Khosravi A, *et al*. Risk factors of in-hospital mortality for isolated on-pump CABG in northeast Iran, 2007-2016. Ir J Med Sci. 2023;192(6):3029–37. doi:10.1007/s11845-023-03298-6
11. Shroyer AL, Hattler B, Wagner TH, Collins JF, Baltz JH, Quin JA, *et al*. Five-year outcomes after on-pump and off-pump CABG. N Engl J Med. 2017;377(7):623–32. doi:10.1056/NEJMoa1614341
12. Marin-Cuartas M, Deo SV, Ramirez P, Verevkin A, Leontyev S, Borger MA, *et al*. Off-pump CABG is safe and effective in patients with severe LV dysfunction. Eur J Cardiothorac Surg. 2022;61(3):705–13. doi:10.1093/ejcts/ezab371
13. Rösler Á, Constantin G, Nectoux P, Holz BS, Letti E, Sales M, *et al*. Thirty-day outcomes of on-pump and off-pump CABG: a Brazilian propensity-score analysis. Braz J Cardiovasc Surg. 2022;37(1):1–6. doi:10.21470/1678-9741-2021-0229
14. Rao YM, Potdar S, Das D, Saha A, Kapoor L, Das M, *et al*. On-pump beating heart vs off-pump myocardial revascularization: a propensity-matched comparison. Indian J Thorac Cardiovasc Surg. 2021;37(6):639–46. doi:10.1007/s12055-021-01209-x
15. Chikwe J, Lee T, Itagaki S, Adams DH, Egorova NN. Long-term outcomes after off-pump vs on-pump CABG by experienced surgeons. J Am Coll Cardiol. 2018;72(13):1478–86. doi:10.1016/j.jacc.2018.07.029
16. Caputti GM, Palma JH, Gaia DF, Buffolo E. Off-pump CABG in selected patients is superior to the conventional approach for severely depressed LV function. Clinics (Sao Paulo). 2011;66(12):2049–53. doi:10.1590/S1807-59322011001200009
17. Bell J, Sartipy U, Holzmann MJ, Hertzberg D. Association between AKI and mortality after CABG was similar in women and men. J Cardiothorac Vasc Anesth. 2022;36(4):962–70. doi:10.1053/j.jvca.2021.11.036
18. Zakkar M, Bruno VD, Guida G, Angelini GD, Chivasso P, Suleiman MS, *et al*. Postoperative AKI defined by RIFLE predicts early outcome and long-term survival in redo CABG. J Thorac Cardiovasc Surg. 2016;152(1):235–42. doi:10.1016/j.jtcvs.2016.02.047
19. Palamuthusingam D, Nadarajah A, Pascoe EM, Craig J, Johnson DW, Hawley CM, *et al*. Postoperative mortality in patients on chronic dialysis after elective surgery: systematic review and meta-analysis. PLoS One. 2020;15(6):e0234402. doi:10.1371/journal.pone.0234402
20. Wang C, Jiang Y, Song Y, Wang Q, Tian R, Wang D, *et al*. Off-pump or on-pump CABG at 30 days: propensity matched analysis. Front Cardiovasc Med. 2022;9:965648. doi:10.3389/fcvm.2022.965648
21. Khan H, Uzzaman M, Benedetto U, Butt S, Raja SG. On- or off-pump CABG for octogenarians: meta-analysis of 27,623 patients. Int J Surg. 2017;47:42–51. doi:10.1016/j.ijsu.2017.09.054
22. Benedetto U, Caputo M, Patel NN, Fiorentino F, Bryan A, Angelini GD. Long-term survival after off-pump vs on-pump CABG: does completeness of revascularization play a role? Int J Cardiol. 2017;246:32–6. doi:10.1016/j.ijcard.2017.04.087