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Perioperative Predictors of Acute Kidney Injury in Off-pump Coronary Artery Bypass Grafting Surgery

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Introduction: Acute kidney injury (AKI) after cardiac surgery is associated with increased morbidity and mortality. Risk factors for AKI during off-pump coronary artery bypass grafting (OPCAB) are poorly understood. Our aim in this study is to identify the relationship between perioperative parameters and AKI following OPCAB.

Method: This prospective observational study was conducted in a single tertiary cardiac center. A total of 175 patients undergoing elective isolated CABG were included in this study over a 2-year period (March 2021 – February 2023). Out of 175 patients, 34 developed acute kidney injury after off-pump coronary artery bypass grafting surgery. Their preoperative, intraoperative, and postoperative findings were compared to identify the independent risk factors for developing postoperative acute kidney injury.

Result: The study was conducted on 175 patients: 113 males (64.5%) and 62 females (35.5%). Their age ranged from 61.81±8.30 years. In the AKI group patients, independent risk factors for developing postoperative AKI consisted of age>70 years (P<0.0001), BMI>30kg/m2 (P=0.015), diabetes, high HbA1c level (>6.5%) (P=<0.001), hypertension (P<0.001), no intake of calcium channel blockers for hypertension (P=<0.001), EF<30%, and timing of angiography before surgery (< 14days) (P=0.005) .

Conclusion: Independent risk factors for developing postoperative AKI consist of age>70 years, BMI>30kg/m2, diabetes, high HbA1c level (>6.5%), hypertension, no intake of calcium channel blockers for hypertension, EF<30%, timing of angiography before surgery (<14 days), Acute MI (<30 days), High serum lactate level at 12 hours post-ICU admission, high vasoactive inotropic score, and requirement of blood transfusion due to various reasons. Among all these variables, mortality was found as a strong predictor in AKI group patients (p=0.016, OR=14.95, 95%CI 1.64-136.08).

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Introduction

Acute kidney injury (AKI) is a serious complication following cardiac surgery, associated with increased morbidity, mortality, and healthcare costs (1). Off-pump coronary artery bypass grafting (OPCABG) surgery, which avoids cardiopulmonary bypass (CPB), was developed to reduce postoperative complications, including AKI (2). AKI remains a significant concern even in OPCABG, with reported incidences ranging from 5% to 30%, depending on the definition and patient population (3).

The pathophysiology of AKI in OPCABG involves multiple events, including hemodynamic instability, systemic inflammation, microemboli, and nephrotoxic insults (4). Identifying perioperative predictors of AKI is crucial for risk stratification, early intervention, and improved patient outcomes. Previous studies have identified factors such as advanced age, chronic kidney disease (CKD), surgery duration, intraoperative hypotension, and transfusion requirements as potential predictors (5,6).

With advancements in surgical techniques, the mechanisms and predictive models for AKI in OPCABG remain incompletely understood. This study aims to evaluate key perioperative risk factors associated with AKI in patients undergoing OPCABG, providing insights for better clinical management and preventive strategies.

Our study is designed to evaluate the perioperative predictors of acute kidney injury in off-pump coronary artery bypass grafting surgery. Our secondary objective was to observe the length of ICU stay, the requirement for renal replacement therapy, and in hospital mortality.

Materials and Methods

This prospective observational study was conducted in a single tertiary cardiac center. The study was approved by our institutional ethical committee. Informed written consent was obtained from the patients or their relatives. (EC/Approval/C.ANESTHE /02/2021/17/03/2021). Eligible patients were adults (>30 years) undergoing elective isolated OPCABG. Exclusion criteria included emergency surgery, preoperative or intraoperative IABP/inotropic support, unfavorable coronary anatomy, preoperative arrhythmias, significant valvular disease (>Grade I MR), combined CABG–valve procedures, conversion to on-pump surgery, significant renal dysfunction, and contrast-induced nephropathy. Significant renal dysfunction was defined as preoperative serum creatinine ≥1.5 mg/dL and/or an estimated glomerular filtration rate (eGFR) <60 mL/min/1.73 m^2, the presence of known chronic kidney disease, renovascular disease, or patients requiring renal replacement therapy. Patients meeting any of these criteria were excluded from the study.

After fulfilling the inclusion criteria and obtaining written informed consent, patients were posted for off-pump isolated coronary artery bypass grafting surgery. Demographic information such as age, gender, height, weight, BMI, NYHA grading, history of other comorbidities like HTN, DM, COPD, PVD, CVA, and smoking history was collected. Preoperative laboratory data, especially serum creatinine and urea, were reported. Preoperative transthoracic echo finding and angiographic reports were reported. The surgical team, surgical time, names of vessels grafted, total intake and urine output, inotropic support, mean arterial pressure during grafting, and any adverse events were noted. Postoperative data such as mean arterial pressure on ICU admission, serum lactate at 6 and 12 hours, Vasoactive-Inotropic Score (VIS) at 12 hours, Hb and Hct levels on the 1st postoperative day were collected. Serum creatinine and urine output in ml (24 hours) on postoperative days 1, 2, and 3 were noted. Other postoperative outcomes such as prolonged mechanical ventilation duration (>24 hrs), re-exploration, requirement of blood transfusion, postoperative AF or any other arrhythmias, days of ICU and hospital stay, patients requiring reintubation, any postoperative MI, stroke, and renal replacement therapy for acute kidney injury, and any death due to cardiac cause were observed.

After receiving the patient in the preoperative preparation area, we obtained wide-bore IV access and placed a 20-G radial arterial line under local anesthesia. After shifting to the operating theatre, we attached all ASA standard monitors like ECG (5 lead), pulse oximetry, and invasive arterial line monitoring. Anesthesia was then induced with a slow IV injection of midazolam 0.1mg/kg, followed by fentanyl at 3- 5 micrograms/kg IV, slow aliquots of IV propofol, and then an IV injection of vecuronium 0.1mg/kg. After 3 minutes of muscle relaxation, we intubated the patient with an appropriatly sized ET tube, confirmed bilateral air entry, and then placed them on controlled mechanical ventilatory support with 50% oxygen and 50% air, and the inhalation agent isoflurane to achieve a MAC of 1. Then a right IJV triple lumen central line was placed in all patients. All patients were heparinized to achieve the required ACT for OPCAB.

Throughout surgery, all patients were continuously monitored by 2-lead electrocardiography (II, V5), pulse oximetry, invasive measurement of arterial blood pressure (SBP, DBP, and MAP) and central venous pressure. Repeated ABGs were monitored and corrective measures were taken to avoid hypoxia, hypercarbia, and acidosis.

Any hemodynamic instability in the operation theater or in the ICU was managed by assessing MAP, CVP, urine output and lactate. The choice of inotropic or vasopressor was decided based on a cumulative assessment using the above parameters. Patients with decreased MAP, decreased CVP, and increased lactate were managed with fluid boluses. Patients with decreased MAP, increased CVP, and increased lactate or decreased urine output were managed with inotropes like adrenaline. Patients with decreased MAP but with signs of increased cardiac output (like normal lactates and good urine output) were managed with vasopressors like noradrenaline and vasopressin. Their doses were adjusted according to hemodynamic response. The requirement for these drugs was assessed using the VIS as proposed by Gaies et al. In the postoperative ICU, acute kidney injury was diagnosed by using KDIGO criteria on the basis of SCr and UO or both.

VIS = Dopamine dose (ug/kg/min) + Dobutamine dose (ug/kg/min) + 10×Milrinone dose (ug/kg/min) + 100×Epinephrine dose (ug/kg/min) + 100×Norepinephrine dose (ug/kg/min) + 10000×Vasopressin dose (IU/kg/min)

Statistical Analysis

Statistical analysis was carried out using SPSS version 20.0 software (SPSS Inc USA). Continuous variables were expressed as Mean ± SD and compared with an unpaired t-test if they followed a normal distribution; otherwise, a Mann-Whitney test was used, and results were expressed as Median and Interquartile range. The chi-square test was used for the comparison of categorical data and to investigate the association between the presence of acute kidney injury and risk factors. A P-value <0.05 was considered statistically significant.

Results

A total of 175 patients undergoing elective isolated off-pump coronary artery bypass grafting were included over two years (March 2021–February 2023). Post-operative AKI occurred in 34 patients, with an overall incidence of 19.49%. The study population comprised 113 males (64.5%) and 62 females (35.5%). Mean age was 61.81 ± 8.30 years, mean height 164 ± 6.32 cm, mean weight 58.86 ± 10.91 kg, and mean BMI 21.72 ± 3.13 kg/m² (Table 1).

Table 1. Demographic data.

	Mean ±SD
Sex	
Male	113
Female	62
Age (years)	61.8114 ± 8.3041
Height (cm)	164.115 ± 6.3244
Weight(kg)	58.862 ±10.9052
BMI(kg/m2)	21.718 ±3.1342

Table 2. Comparisons of demographic data between two groups.

	AKI	Non-AKI	P VALUE
	(No. Pts 34)	(No. Pts 141)	
Age (years)			
<60 years (72 pts)	10	62	P = 0.055
60-70 years (75 pts)	19	56	P = 0.035
>70 years (28 pts)	5	23	P<0.0001
BMI (kg/m2)			
<18 (20 pts)	3	17	P<0.005
18-24.99 (115 pts)	23	92	P=0.059
25-29.99 (24 pts)	5	19	P=0.0002
>30 (16 pts)	3	13	P=0.0015

Baseline demographic parameters were comparable between AKI and non-AKI groups. Patients aged >70 years had a significantly higher incidence of AKI ($p < 0.0001$).Both obese patients (BMI > 30 kg/m^2) and underweight patients (BMI < 18 kg/m^2) were at increased risk of developing AKI ($p < 0.005$) (Table 2).

Comorbidities including hypertension, diabetes mellitus, smoking, peripheral vascular disease, cerebrovascular accident, and COPD were analyzed (Table 3). Among 53 diabetic patients, 16 developed AKI ($p < 0.05$), and poor glycemic control (HbA1c > 6.5%) was present in 12 of these patients ($p < 0.05$). Of 64 patients with hypertension on regular treatment, 16 developed AKI ($p < 0.05$). Patients receiving calcium channel blockers showed a significantly lower incidence of AKI (2 of 21 patients, $p < 0.05$). Among 69 chronic smokers, 10 developed post-operative AKI ($p < 0.05$). AKI occurred in 5 of 28 patients in NYHA class III and in 1 of 7 patients in NYHA class IV.

Preoperative laboratory investigations, chest X-ray, ECG, echocardiographic findings, angiographic details, timing of angiography before surgery, and EuroSCORE II were recorded. Echocardiographic parameters, angiography-to-surgery interval, and history of acute myocardial infarction within 30 days were comparable between the two groups (Table 4). Patients were included irrespective of left ventricular ejection fraction, with only grade I mitral regurgitation. AKI occurred in 17 of 88 patients with EF ≥ 40% ($p > 0.05$) and in 7 of 35 patients with EF ≤ 30% ($p < 0.05$). Surgery performed within 14 days of coronary angiography was associated with a higher incidence of AKI (14 of 72 patients, $p < 0.05$). A recent acute myocardial infarction (<30 days) was also significantly associated with AKI (3 of 15 patients, $p = 0.0035$).

All procedures were performed by a single surgical team, and grafting details were statistically comparable.

Table 3. Comparisons of comorbidities between two groups.

	AKI	Non-AKI	P VALUE
	(No. Pts 34)	(No. Pts 141)	
Diabetes Mellitus(53pts)	16	37	P=0.0001
HbA1C			
= >6.5% (36pts)	12	24	P=0.0095
<6.5% (17pts)	4	13	P>0.05
Hypertension (64 pts)	15	49	P<0.005
On CCB (21 pts)	2	19	P<0.0001
COPD (46 pts)	4	42	P>0.05
H/O Smoking (69 pts)	10	50	P<0.0001
H/O PVD (38 pts)	5	33	P>0.05
H/O CVA (3 pts)	1	2	P=1.0000
NYHA Grades			
Class 3 (28 pts)	5	23	P>0.05
Class 4 (7 pts)	1	6	P=0.0325

Post-operative ICU variables, including mean arterial pressure on admission, VIS at 12 hours, serum lactate levels at 12 hours, timing of extubation, duration of ICU stay, re-intubation, re-exploration, need for renal replacement therapy, in-hospital mortality, and postoperative complications were analyzed (Table 5).

Serum lactate ≥4 mmol/L at 12 hours was associated with a higher incidence of AKI (13 of 40 patients, $p < 0.05$). The mean VIS score was significantly higher in the AKI group compared to the non-AKI group (12.11 ± 0.02 vs 6.88 ± 0.06; $p < 0.05$). AKI was more frequent in patients requiring perioperative blood transfusion (9 of 56 patients, $p < 0.05$) and in those undergoing re-exploration surgery (6 of 23 patients, $p < 0.05$). Patients who developed AKI had a significantly longer ICU stay compared to non-AKI patients (6.55 ± 0.32 vs 3.92 ± 0.78 days; $p < 0.05$). In-hospital mortality was higher in the AKI group, with 3 deaths among 34 AKI patients ($p < 0.05$). One of these patients required renal replacement therapy, with a mortality rate of 33.3% among RRT-requiring AKI patients. Multivariate regression analysis identified significant perioperative predictors of AKI, as summarized in Table 6.

Discussion

In this study, the incidence of AKI following isolated OPCABG was 19.49% based on KDIGO criteria, consistent with previously reported rates of 5–40% (3,7–10). Although overall in-hospital mortality was 4%, patients who developed AKI experienced substantially higher mortality (8.82%), which further increased among those requiring renal replacement therapy (33.3%), underscoring the adverse prognostic impact of AKI after OPCABG.

Advanced age and obesity emerged as significant predictors of AKI. Patients aged >70 years and those with a BMI >30 kg/m^2 were at increased risk, findings that align with earlier studies suggesting age-related decline in renal reserve and heightened vulnerability to perioperative hemodynamic stress (1,3–6,11,12). Similarly, severely reduced left ventricular ejection fraction (<30%) was strongly associated with AKI, likely reflecting compromised renal perfusion in the setting of low cardiac output (13,14).

Table 4. Preoperative data comparison between two groups.

	AKI	Non-AKI	P VALUE
	(No. Pts 34)	(No. Pts 141)	
ECHO (%LVEF)			
-≥40% EF (88 pts)	17	71	P>0.05
-30-40% EF (52 pts)	10	42	P<0.0001
-≤30% EF (35 pts)	7	28	P<0.0001
Timing of angiography before surgery			
->14 days (103 pts)	20	83	P>0.05
<14 days (72 pts)	14	58	P<0.05
Acute MI <30 days (15pts)	3	12	P=0.0035

Table 5. Postoperative data comparisons between two groups.

	AKI	Non-AKI	P VALUE
	(No. Pts 34)	(No. Pts 141)	
S. Lactate (mmol/l)			
≤2.5 (70 pts)	6	64	P>0.05
2.5-3.9 (65 pts)	15	50	P<0.0001
≥4 (40 pts)	13	27	P=0.0037
Vasoactive Ionotropic Score (Mean Value)	12.11 ± 0.023	6.88 ± 0.06	P<0.0001
Re-exploration (23 pts)	6	17	P=0.0032
H/O Blood Transfusion (56 pts)	9	47	P<0.0001
Length of ICU stay in days (mean value)	6.55 ± 0.32	3.92 ± 0.78	P<0.0001
In Hospital Mortality (7 pts)	3	4	P<0.05

Table 6. Factor that associated with acute kidney injury.

	B	S.E.	Wald	Sig.	Exp(B)	95% C.I.for EXP(B)	95% C.I.for EXP(B)
HTN	0.969	0.586	2.737	0.098	2.635	0.836	8.307
On CCB For HTN	-3.621	1.944	3.467	0.063	0.027	0.001	1.210
Smoking	0.241	0.565	0.182	0.670	1.273	0.420	3.853
NYHA Grade	1.518	1.209	1.577	0.209	4.565	0.427	48.824
HbA1C (%)	-6.053	1.675	13.064	0.000	0.002	0.000	0.063
ECHO(%EF)	-0.221	0.583	0.144	0.704	0.802	0.256	2.512
Acute MI<30 days	-1.680	1.290	1.697	0.193	0.186	0.015	2.334
Re-exploration	-0.253	0.732	0.120	0.729	0.776	0.185	3.259
Blood Transfusion	-2.652	0.917	8.360	0.004	0.071	0.012	0.426
In Hospitsl Mortality	2.705	1.127	5.764	0.016	14.954	1.643	136.080

The timing of coronary angiography prior to surgery also influenced AKI risk. Patients undergoing OPCABG within 14 days of angiography had a significantly higher incidence of AKI, supporting prior observations that recent contrast exposure may predispose to postoperative renal dysfunction even in the absence of overt contrast-induced nephropathy (15,16).

Diabetes mellitus was identified as an independent risk factor for AKI, with poor glycemic control (HbA1c >6.5%) further increasing susceptibility. These findings emphasize the importance of optimizing metabolic status before cardiac surgery (17–20). Hypertension was similarly associated with AKI; however, patients receiving calcium channel blockers demonstrated a lower incidence, suggesting a potential nephroprotective effect, possibly through improved renal microvascular perfusion (21).

Markers of advanced cardiac disease and perioperative instability, including NYHA class III–IV, surgical re-exploration, and postoperative blood transfusion, were also strongly associated with AKI. These factors likely contribute through recurrent hypotension, inflammatory activation, impaired oxygen delivery, and endothelial dysfunction, as supported by previous reports (9-12, 22-24).

Overall, AKI after isolated OPCABG appears to be multifactorial, resulting from the interaction of preoperative patient characteristics and perioperative insults. Identification of high-risk patients may facilitate early implementation of renal-protective strategies and improve postoperative outcomes.

Limitations

This study has several limitations. It was a single-center observational study with a relatively limited sample size, which may restrict the generalizability of the findings. Although multiple perioperative variables were analyzed, novel renal biomarkers were not assessed, and AKI was defined solely using serum creatinine–based KDIGO criteria. Additionally, preoperative AKI risk prediction models were not applied, limiting comparison with established scoring systems. Long-term renal outcomes after hospital discharge were also not evaluated. Future multicenter studies with larger cohorts and longer follow-up are warranted to validate these findings and refine perioperative renal risk stratification strategies.

Conclusion

Acute kidney injury following isolated coronary artery bypass grafting surgery occurs with some frequency, and it is of great clinical importance related to poor postoperative outcomes, prolonged ICU stay, requirement of renal replacement therapy on a temporary or permanent basis, and high mortality rates. Independent risk factors for developing postoperative acute kidney injury consist of age>70 years, BMI>30kg/m2, diabetes, high HbA1c level (>6.5%), hypertension, no intake of calcium channel blockers for hypertension, EF<30%, timing of angiography before surgery (<14days), acute MI (<30 days), high serum lactate level at 12 hours post-ICU admission, high vasoactive inotropic score, and requirement of blood transfusion due to various reasons. Among all these variables mortality was found as a strong predictor in AKI group patients (p=0.016, or=14.95, 95%CI 1.64-136.08).These factors provide an easy and accurate model to predict postoperative acute kidney injury in patients undergoing isolated off-pump coronary artery bypass grafting surgery.

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Conflict of interest statement

All authors declare that they have no conflict of interest.

Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to restrictions because the information could compromise the privacy of research participants.

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