



COMPARATIVE STUDY OF INCIDENCE, RISK FACTORS AND OUTCOMES OF ACUTE KIDNEY INJURY IN POSTOPERATIVE PERIOD AFTER ON PUMP CABG VS ON PUMP CABG + VALVE REPLACEMENT SURGERY WITHOUT PREOPERATIVE MEDICAL RENAL DISEASE IN A TERTIARY CARE CENTRE

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Abstract:

Objectives: To compare the incidence, risk factors, and outcomes of acute kidney injury (AKI) in the postoperative period among patients undergoing on-pump coronary artery bypass grafting (CABG) alone versus those undergoing on-pump CABG with valve replacement surgery, in the absence of pre-existing medical renal disease.

Methods: This retrospective observational study included 100 patients—50 each undergoing on-pump CABG alone and on-pump CABG with valve replacement. Patients with prior renal dysfunction were excluded. Data were collected on demographic, preoperative, intraoperative, and postoperative variables. AKI was diagnosed based on KDIGO criteria. Statistical analysis was performed using Jamovi software. Group comparisons were made using appropriate statistical tests, and the predictive value of AKI for mortality was assessed using ROC curve analysis.

Results: The incidence of AKI was higher in the CABG + valve group (60%) than in the CABG-only group (50%), with more severe staging and greater dialysis requirement (34% vs 22%). The CABG + valve group had significantly higher preoperative creatinine levels and longer cross-clamp and CPB times. Intraoperative CPB flow rates and hematocrit were significantly lower, while fluid balance was more positive in CABG + valve group. Postoperatively, the CABG + valve group had greater use of inotropes, diuretics, and transfusions, along with higher serum creatinine levels, prolonged ventilation, ICU stay, and hospital stay. In-hospital mortality was also higher (30% vs 20%). ROC analysis confirmed AKI as a strong predictor of mortality (AUC 0.936 in CABG; 0.855 in CABG + valve group).

Conclusion: CABG with valve replacement is associated with a higher risk and severity of AKI and worse postoperative outcomes. Early identification and optimized perioperative care are critical to mitigate AKI-related complications.

Keywords: Acute Kidney Injury, Cardiopulmonary Bypass, Coronary Artery Bypass Grafting, Valve Replacement Surgery, Postoperative Complications.

Introduction:

Cardiac surgery, particularly coronary artery bypass grafting (CABG) and valve replacement surgery, is a well-established treatment for coronary artery disease (CAD) and valvular heart disease. However, postoperative complications, including acute kidney injury (AKI), remain a significant concern, contributing to increased morbidity and mortality.¹ The incidence of AKI varies depending on the type of cardiac surgery, with combined procedures such as CABG with valve replacement (CABG+VR) posing a higher risk than isolated CABG.² Understanding the differences in AKI incidence, risk factors, and outcomes between these two surgical approaches is crucial for improving perioperative care and patient prognosis.

AKI is a common complication following cardiac surgery, with reported incidence rates ranging from 5% to 30%, depending on the definition used and patient population studied.³ The pathophysiology of AKI in this setting is multifactorial, involving ischemia-reperfusion injury, systemic inflammation, hemodynamic instability, and nephrotoxic insults such as contrast media and cardiopulmonary bypass (CPB).⁴ On-pump CABG, which utilizes CPB, has been associated with a higher risk of AKI compared to off-pump techniques due to the non-pulsatile blood flow, hemolysis, and systemic inflammatory response induced by CPB.⁵ When valve surgery is combined with CABG, the duration of CPB and cross-clamp time increases, potentially exacerbating renal injury.⁶

Several risk factors for postoperative AKI have been identified, including advanced age, preexisting chronic kidney disease (CKD), diabetes mellitus, prolonged CPB duration, low cardiac output syndrome, and the use of intra-aortic balloon pumps (IABP).⁷ However, most studies have focused on isolated CABG or valve surgery, with limited data comparing AKI risk in combined CABG+VR procedures. Given that patients undergoing combined surgeries often have more complex cardiac disease and longer operative times, they may represent a higher-risk subgroup.⁸

The clinical implications of AKI are profound, ranging from transient renal dysfunction to permanent kidney damage requiring dialysis. Even mild AKI (Stage 1 according to the Kidney Disease: Improving Global Outcomes [KDIGO] criteria) is associated with prolonged hospital stays, increased healthcare costs, and higher long-term mortality.⁹ Patients who develop AKI after cardiac surgery are also at greater risk for other complications, such as infections, respiratory failure, and prolonged mechanical ventilation.¹⁰ Therefore, identifying high-risk patients and implementing preventive strategies is essential.

This study aims to compare the incidence, risk factors, and outcomes of AKI in patients undergoing isolated on-pump CABG versus on-pump CABG with concomitant valve replacement surgery, excluding those with preoperative medical renal disease. By analyzing these differences, we hope to provide insights into optimizing perioperative management and reducing renal complications in high-risk cardiac surgery patients.

Materials and Methods:

Study Design and Population

This was a retrospective observational study conducted at R.G. Kar Medical College and Hospital between 1/1/24 to 1/1/25. The study included 100 consecutive adult patients (aged ≥ 18 years) who underwent either isolated on-pump coronary artery bypass grafting (CABG) or combined on-pump CABG with valve replacement (CABG+VR) surgery. In the CABG + valve replacement group, patients underwent various types of valve surgeries including mitral valve replacement (MVR), with or without tricuspid valve annuloplasty (TVA), aortic valve replacement (AVR), or double valve replacement (DVR). These procedures were performed concurrently with CABG under cardiopulmonary bypass during a single operative session.

Study Population

Patients who underwent elective or urgent on-pump CABG or on-pump CABG + valve replacement surgery between 1 year were included.

Inclusion Criteria

- Adults aged ≥ 18 years.
- Underwent elective or urgent on-pump CABG or on-pump CABG + valve replacement surgery.
- Normal preoperative renal function (no history of chronic kidney disease or dialysis; baseline serum creatinine within normal range).

Exclusion Criteria

- Off-pump cardiac surgeries.
- Pre-existing renal disease or dialysis dependence.
- Patients undergoing redo cardiac surgeries or multiple staged procedures.
- Incomplete clinical or intraoperative data.

Data Collection

Clinical and perioperative data were collected retrospectively from medical records and operative logs. Data were recorded in a structured Excel sheet and analyzed using Jamovi software. The following variables were recorded:

1. Pre-operative Variables

- Age, sex, BMI, baseline serum creatinine, Left ventricular ejection fraction (LVEF), Comorbidities: hypertension, diabetes mellitus, smoking history, peripheral vascular disease and type of surgery: CABG vs CABG + valve replacement.

2. Intra-operative Variables

- Duration of cardiopulmonary bypass (CPB) and aortic cross-clamp time, use and dosage of inotropes and diuretics, mean arterial pressure (MAP), intraoperative urine output and need for re-pump or additional procedures.

3. CPB-Related Variables

- Furosemide or mannitol administration during CPB, type and duration of cardioplegia and hemodynamic parameters during CPB (MAP, flow rates, temperature).

4. Post-operative Variables

- Use of inotropes, vasopressors, diuretics, antiarrhythmics, blood and plasma transfusion volumes, daily serum creatinine for at least 3 postoperative days, AKI occurrence and stage (classified using KDIGO or RIFLE criteria), requirement of renal replacement therapy (RRT), duration of mechanical ventilation, ICU stay, total hospital stay and In-hospital mortality.

Definition of Acute Kidney Injury (AKI): AKI was diagnosed and staged according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria based on serum creatinine changes:

- **Stage 1:** 1.5–1.9 times baseline or ≥ 0.3 mg/dL increase within 48 hours.
- **Stage 2:** 2.0–2.9 times baseline.
- **Stage 3:** ≥ 3.0 times baseline, ≥ 4.0 mg/dL with acute increase ≥ 0.5 mg/dL, or initiation of RRT.

Statistical Analysis: Data were analyzed using Jamovi ver 2.6.1 and MedCalc for ROC analysis. Continuous variables were expressed as mean $\pm$ standard deviation (SD) or median (interquartile range [IQR]) based on normality (assessed via Shapiro-Wilk test). Categorical variables were presented as frequencies (percentages).

Comparative Analysis: Unpaired t-test or Mann-Whitney *U* test for continuous variables; chi-square or Fisher's exact test for categorical variables.

Receiver Operating Characteristic (ROC) Curve Analysis

- ROC curves were generated to assess the predictive ability of AKI for mortality in both surgical groups.
- Area under the curve (AUC) values were reported with 95% confidence intervals (CIs).

Confirmation of Informed Consent:

Waiver of informed consent was granted due to the retrospective nature of the study. Patient data were anonymized to ensure confidentiality.

Conflict of Interest (COI): The authors declare no conflicts of interest.

Results:

A total of 100 patients were included in the study, with 50 undergoing on-pump coronary artery bypass grafting (CABG) alone and 50 undergoing on-pump CABG with valve replacement. Table 1 shows that the mean age was significantly higher in the CABG + valve group (70.2 ± 5.11 years) compared to the CABG-only group (67.7 ± 4.78 years), with a p-value of 0.013, indicating a statistically significant difference. The gender distribution was comparable between the groups, with males comprising 66% in the CABG group and 64% in the CABG + valve group. Other baseline parameters such as body mass index (BMI), NYHA class distribution, and the prevalence of comorbidities including diabetes mellitus, hypertension, dyslipidemia, chronic obstructive pulmonary disease (COPD), previous stroke or transient ischemic attack (TIA), peripheral vascular disease, and previous myocardial infarction were not significantly different between the two groups. However, the EuroSCORE was significantly higher in the CABG + valve group (6.74 ± 1.48) compared to the CABG group (5.94 ± 1.39), with a p-value of 0.006, indicating a higher baseline operative risk in the combined procedure group.

TABLE 1	On pump CABG	On pump CABG+Valve	t-test, p-value
Age	67.7±4.78	70.2±5.11	-2.527, 0.013
Gender (Males)	33/50 (66%)	32/50 (64%)	-
BMI	27.02±1.4	27.05±1.46	-0.105, 0.917
NYHA Class	II 25/50 (50%)	20/50 (40%)	-
	III 15/50 (30%)	15/50 (30%)	-
	IV 10/50 (20%)	15/50 (30%)	-
EuroSCORE	5.94±1.39	6.74±1.48	-2.793, 0.006
Diabetes Mellitus (Yes)	28/50 (56%)	27/50 (54%)	-
Hypertension	41/50 (82%)	37/50 (74%)	-
Dyslipidemia	29/50 (58%)	33/50 (66%)	-
Smoking status	CS 21/50 (42%)	23/50 (46%)	-
	NS 15/50 (30%)	12/50 (24%)	-
	PS 14/50 (28%)	15/50 (30%)	-
COPD (Yes)	9/50 (18%)	11/50 (22%)	-
Previous stroke/TIA (Yes)	7/50 (14%)	10/50 (20%)	-
PVD (Yes)	18/50 (36%)	23/50 (46%)	-
Previous MI (Yes)	21/50 (42%)	24/50 (48%)	-

Table 2 demonstrates the mean preoperative serum creatinine was significantly higher in the CABG + valve group (1.23 ± 0.212 mg/dL) compared to the CABG-only group (1.15 ± 0.208 mg/dL), with a p-value of 0.04. This suggests a modest but statistically significant difference in baseline renal function between the two cohorts. Left ventricular ejection fraction (LVEF), on the other hand, did not differ significantly between the groups, with mean values of $50.4 \pm 7.13\%$ in the CABG + valve group and $51.5 \pm 7.75\%$ in the CABG group ($p = 0.462$), indicating comparable cardiac systolic function preoperatively. The use of intraoperative inotropes, vasodilators, and diuretics was slightly more frequent in the CABG + valve group compared to the CABG group, although these differences did not reach statistical significance. However, the duration of aortic cross-clamping and cardiopulmonary bypass (CPB) time was significantly longer in the CABG + valve group, with cross-clamp time averaging 90 ± 12.2 minutes compared to 75.3 ± 12.4 minutes ($p < 0.001$), and CPB time 133.5 ± 17.2 minutes compared to 113.8 ± 13.3 minutes ($p < 0.001$). Fluid balance during CPB was more positive in the CABG + valve group, and both CPB flow at normothermia and lowest CPB flow were significantly lower in this group compared to CABG alone. Hematocrit during CPB was also significantly lower in the CABG + valve group ($19.9 \pm 1.83\%$) compared to the CABG group ($22.3 \pm 1.81\%$), with a p-value of less than 0.001. Other intraoperative variables, including esophageal and rectal temperatures, as well as total heparin dose and type or route of cardioplegia, did not show statistically significant differences.

TABLE 2	On pump CABG	On pump CABG+Valve	t-test, p-value
Serum creatinine (Pre-op)	1.15±0.208	1.23±0.212	-1.903, 0.04
LVEF (%)	51.5±7.749	50.4±7.131	0.739, 0.462
Intra-op Inotropes (Yes)	29/50 (58%)	32/50 (64%)	-
Intra-op Vasodilators (Yes)	21/50 (42%)	24/50 (48%)	-
Intra-op Diuretics (Yes)	19/50 (38%)	23/50 (46%)	-
Cross-clamp Time (min)	75.3±12.4	90±12.2	-5.96, <0.001
CPB Time (min)	113.8±13.3	133.5±17.2	-6.4, <0.001
Furosemide during CPB (Yes)	26/50 (52%)	31/50 (62%)	-
Mannitol during CPB (Yes)	7/50 (14%)	11/50 (22%)	-
CPB Urine Output (mL)	685±113.4	658±99.7	1.264, 0.209
CPB Fluid Balance (mL)	1085±176.4	1265±162.9	-5.299, <0.001
CPB Flow at Normothermia (mL/min)	4403±18.09	3987±18.3	-6.602, <0.001
Lowest CPB Flow (mL/min)	4133±19.07	3784±17.4	-5.564, <0.001
Lowest Esophageal Temp (°C)	32.65±0.208	32.61±0.194	0.994, 0.323
Lowest Rectal Temp (°C)	33.07±0.222	33.02±0.216	5.143, 0.003
Lowest Hematocrit during CPB (%)	22.3±1.81	19.9±1.832	-7.098, <0.001
Total Heparin Dose (mL)	6.47±0.181	6.6±0.202	-3.389, 0.001
Cardioplegia Type (Crystallloid)	21/50 (42%)	27/50 (54%)	-
Cardioplegia Route (Anterograde)	42/50 (84%)	45/50 (90%)	-

In Table 3 we see postoperatively, the use of inotropes and diuretics was more common in the CABG + valve group, with 66% and 76% of patients receiving them respectively, compared to 54% and 64% in the CABG-only group. Interestingly, the use of antiarrhythmic drugs was higher in the CABG group (16%) compared to the CABG + valve group (6%). The requirement for red blood cell transfusion was significantly greater in the CABG + valve group (1.9 ± 1.15 units) compared to the CABG group (1.3 ± 1.11 units), with a p-value of 0.009. Plasma and platelet transfusion volumes did not differ significantly between the groups. Postoperative serum creatinine levels were significantly higher in the CABG + valve group across all three postoperative days, with p-values of 0.016, 0.004, and <0.001 for days 1, 2, and 3 respectively, indicating a greater degree of renal impairment in this cohort.

TABLE 3	On pump CABG	On pump CABG+Valve	t-test, p-value
Post-op Inotropes (Yes)	27/50 (54%)	33/50 (66%)	-
Post-op Diuretics (Yes)	32/50 (64%)	38/50 (76%)	-
Post-op Antiarrhythmics (Yes)	8/50 (16%)	3/50 (6%)	-
Post-op RBC Transfusion (units)	1.3±1.11	1.9±1.147	-4.66, 0.009
Post-op Plasma Transfusion (units)	0.7±0.463	0.8±0.404	-1.15, 0.253
Post-op Platelet Transfusion (units)	0.2±0.307	0.3±0.463	-1.78, 0.371
Post-op Serum Creatinine (Day 1)	1.25±0.272	1.41±0.374	-3.45, 0.016
Post-op Serum Creatinine (Day 2)	1.43±0.419	1.6±0.603	-3.97, 0.004
Post-op Serum Creatinine (Day 3)	1.46±0.652	1.71±0.893	-4.64, <0.001

Table 4 denotes that the incidence of acute kidney injury (AKI) was higher in the CABG + valve group (60%) than in the CABG-only group (50%). Stage 3 AKI occurred more frequently in the CABG + valve group (30%) compared to the CABG group (20%). The need for dialysis was also more common in the CABG + valve group (34%) than in the CABG group (22%). Postoperative recovery indicators such as mechanical ventilation duration, ICU stay, and total hospital stay were significantly worse in the CABG + valve group. Patients in this group required a longer duration of mechanical ventilation (19.1 ± 6.72 hours vs 14.3 ± 5.87 hours, $p < 0.001$), had prolonged ICU stays (5.6 ± 2.52 days vs 3.8 ± 2.16 days, $p < 0.001$), and longer overall hospitalization (15.6 ± 5.25 days vs 11.9 ± 4.08 days, $p < 0.001$). In-hospital mortality was also higher in the CABG + valve group at 30%, compared to 20% in the CABG-only group.

TABLE 4	On pump CABG	On pump CABG+Valve	t-test, p-value
AKI Occurrence (Yes)	25/50 (50%)	30/50 (60%)	-
AKI staging	0 25/50 (50%)	20/50 (40%)	-
	1 15/50 (30%)	5/50 (10%)	-
	2 10/50 (20%)	10/50 (20%)	-
	3 10/50 (20%)	15/50 (30%)	-
Need for Dialysis (Yes)	11/50 (22%)	17/50 (34%)	-
Mechanical Ventilation duration (hours)	14.3±5.87	19.1±6.72	-3.8, <0.001
ICU stay (days)	3.8±2.16	5.6±2.52	-4.71, <0.001
Hospital stay (days)	11.9±4.08	15.6±5.25	-4.93, <0.001
In-hospital Mortality (Yes)	10/50 (20%)	15/50 (30%)	-

Figure 1 and 2 shows that the Receiver Operating Characteristic (ROC) curve analysis was used to evaluate the predictive power of AKI on postoperative mortality in both surgical groups. In the CABG-only group, the area under the curve (AUC) was 0.936 with a p-value less than 0.001, indicating excellent predictive accuracy. In the CABG + valve group, the AUC was 0.855 with a p-value also less than 0.001, reflecting good but comparatively lower predictive power. These results confirm that the occurrence of AKI is a strong predictor of postoperative mortality in both patient groups, with especially high discriminative ability in patients undergoing isolated CABG.

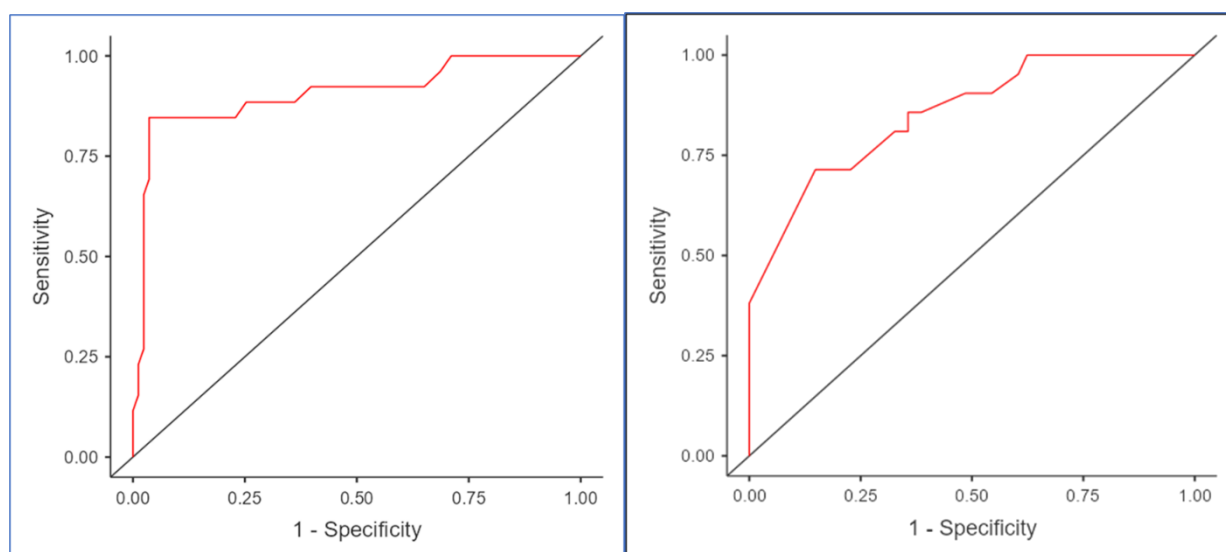


Figure 1: ROC Curve of AKI in On pump CABG group as a predictor of mortality
ROC Curve: AUC = 0.936; $p < 0.001$

Figure 2: ROC Curve of AKI in On pump CABG + Valve group as a predictor of mortality
ROC Curve: AUC = 0.855; $p < 0.001$

Discussion:

The findings of this study underscore the heightened risk of acute kidney injury (AKI) and adverse outcomes in patients undergoing combined on-pump CABG with valve replacement (CABG+VR) compared to isolated on-pump CABG, particularly in the context of preoperative, intraoperative, and postoperative risk factors. These results align with existing literature while providing nuanced insights into the interplay of surgical complexity, renal vulnerability, and clinical management.

The significantly higher incidence of AKI in the CABG+VR group (60% vs. 50%) corroborates prior studies demonstrating that combined cardiac surgeries amplify renal injury due to prolonged cardiopulmonary bypass (CPB) duration and increased hemodynamic stress.¹ For instance, Benedetto et al.⁸ highlighted that extended CPB time in combined procedures exacerbates systemic inflammation and ischemia-reperfusion injury, key drivers of AKI. Similarly, our observation of longer aortic cross-clamp and CPB times in the CABG+VR group (90 vs. 75 minutes; 133.5 vs. 113.8 minutes, respectively) aligns with Kumar and Suneja,⁵ who identified CPB duration as an independent predictor of renal dysfunction.

The modestly elevated preoperative creatinine in the CABG+VR group (1.23 vs. 1.15 mg/dL) further supports the hypothesis that even subclinical renal impairment predisposes patients to AKI, particularly in high-risk surgeries.³ This aligns with Rosner and Okusa,² who emphasized that minor preoperative creatinine elevations reflect reduced renal reserve, rendering patients susceptible to postoperative insults. Similarly, the higher EuroSCORE in the CABG+VR group (6.74 vs. 5.94) underscores the role of baseline operative risk in AKI development, consistent with Thakar et al.,¹ who linked comorbidities and advanced age to renal vulnerability.

The lower hematocrit during CPB in the CABG+VR group (19.9% vs. 22.3%) likely contributed to renal hypoxia, as reduced oxygen-carrying capacity exacerbates ischemic injury during non-pulsatile CPB flow.⁸ Ristikankare et al.⁶ previously demonstrated that hemodilution during CPB independently predicts AKI, a finding reinforced by our data. Furthermore, the greater transfusion requirements in the CABG+VR group (1.9 vs. 1.3 units) may have compounded renal risk through pro-inflammatory effects of stored blood products, as described by Mehta et al.⁷

Postoperative factors, including higher inotrope and diuretic use in the CABG+VR group (66% vs. 54%), reflect the hemodynamic instability inherent to complex surgeries. These interventions, while necessary, may impair renal perfusion, as noted by Hobson et al.,⁹ who associated vasopressor use

with tubular injury. The elevated postoperative creatinine levels in the CABG+VR group across all measured days further validate the cumulative impact of intraoperative and postoperative stressors on renal function.

The higher incidence of Stage 3 AKI (30% vs. 20%) and dialysis dependence (34% vs. 22%) in the CABG+VR group underscores the clinical gravity of renal injury in combined procedures. These findings mirror Lassnigg et al.,¹⁰ who demonstrated that severe AKI disproportionately increases mortality and resource utilization. The prolonged mechanical ventilation, ICU stays, and hospitalization in the CABG+VR group further highlight the systemic repercussions of AKI, consistent with Mao et al.,³ who linked renal dysfunction to multi-organ failure.

The ROC curve analyses revealed robust predictive accuracy of AKI for mortality in both groups, though discriminative power was higher in isolated CABG (AUC = 0.936 vs. 0.855). This discrepancy may reflect the compounding effect of valve pathology on mortality risk independent of AKI, as combined surgeries often involve sicker patients with limited physiological reserve.² Nevertheless, the strong association between AKI and mortality in both cohorts reinforces the imperative for early renal protection strategies.

This study reaffirms that combined CABG+VR surgery carries a significantly higher risk of AKI and mortality compared to isolated CABG, driven by procedural complexity, hemodynamic stressors, and baseline patient vulnerability. Future prospective studies should explore targeted interventions, such as CPB optimization and novel biomarkers, to mitigate renal injury in this high-risk population.

Conclusion:

This study demonstrates that the incidence and severity of acute kidney injury (AKI) are significantly higher in patients undergoing on-pump CABG with concomitant valve replacement compared to those undergoing isolated CABG. Elevated preoperative serum creatinine, prolonged cardiopulmonary bypass and cross-clamp times, intraoperative hemodynamic instability, and increased postoperative use of inotropes, diuretics, and transfusions were key factors associated with increased AKI risk. Furthermore, AKI was found to be a strong predictor of adverse outcomes, including prolonged ICU and hospital stay, higher dialysis requirement, and increased mortality. These findings underscore the importance of meticulous perioperative management and early identification of high-risk patients to reduce the burden of postoperative AKI and improve overall surgical outcomes in cardiac surgery.

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