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ORIGINAL ARTICLE

Cardiac Surgery Associated Acute Kidney Injury - Incidence, Risk Factors, Outcomes, and Risk Score Validation from a Single Centre in Bahrain

Abdulla Faisal Alshaiji[1]*, Shailendra Kumar Motwani[1], Helen Saunders[1], Swaraj Sathyan[1], Sai Nagendra Banovath[1], Nazar Bukamal[1]

[1]Mohammed Bin Khalifa Bin Salman Al Khalifa Specialist Cardiac Centre, Awali, Bahrain.

***Corresponding author:**

Dr. Abdulla Faisal Alshaiji, Mohammed Bin Khalifa Bin Salman Al Khalifa Specialist Cardiac Centre, Awali, Bahrain; Tel. No.: (+973) 39515219; Email: alshaiji.abdulla@gmail.com

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Abstract

Background: Cardiac surgery-associated acute kidney injury (CSA-AKI) is a common complication in patients undergoing cardiac surgery. Early prediction of acute kidney injury (AKI) is crucial to estimate and communicate the prognosis and outcome of surgery. This research is particularly significant as it addresses the need for validation of risk scores in non-Caucasian populations with a higher incidence of risk factors, potentially leading to improved patient care and outcomes.

Objective: This prospective study aimed to investigate the association between socio-demographic and clinical variables in patients undergoing cardiac surgery in a single center in Bahrain and their correlation with a predictive risk score.

Methods: This comprehensive study included 100 patients who underwent cardiac surgery. The distribution of study subjects was meticulously assessed based on the kidney disease: Improving Global Outcomes (KDIGO) classification for AKI. The association of AKI with socio-demographic and clinical variables was rigorously analyzed using chi-square tests and logistic regression analysis and compared to the predicted incidence from the Acute Kidney Injury after Cardiac Surgery (AKICS) score, ensuring the reliability and accuracy of our findings.

Results: Among the study subjects, 65% were not affected by acute kidney injury (AKI). In contrast, 19% were classified as having Stage 1 AKI, 8% as Stage 2, and 8% as Stage 3. Additionally, 2% of the patients required dialysis. The findings of our study underscore the significant impact of AKI on hospital stay and the need for dialysis. Female gender, previous myocardial infarction, UF heparin use, and elevated preoperative creatinine levels were significantly associated with AKI. The AKICS score was found to predict AKI in our patients, with a sensitivity of 91% and a specificity of 46.9%.

Conclusion: Female gender, previous myocardial infarction, UF heparin use, and elevated preoperative creatinine levels were found to be independent predictors of AKI. We found that patients with AKI had a significantly longer hospital stay duration. The AKICS score has been validated in our local cohort of Middle Eastern patients with high sensitivity.

Keywords: Acute kidney injury; Cardiac surgery; Risk factors; Socio-demographic factors; Clinical variables

Introduction

Cardiac surgery-associated acute kidney injury (CSA-AKI) is a common complication (17-49%) of patients undergoing cardiac surgery,[1] with around 2-6% of patients requiring renal replacement therapy. This complication is independently associated with increased mortality, prolonged hospital stays, and treatment costs.[2] In those requiring renal replacement therapy, the mortality risk is increased up to 60%.[3] Early prediction of AKI is essential to estimate and communicate the prognosis and outcome of surgery to patients and to identify high-risk candidates to target early prevention.

Different prognostic risk scores are available to prevent the risk of AKI and dialysis requirement post-cardiac surgery, but they have not been validated in different population cohorts. The Cleveland Clinic score has been validated in North America for predicting dialysis requiring AKI but lacks adequate discrimination and calibration in non-North American populations.[4]

The AKICS score was developed using data from 603 patients undergoing cardiac surgery in Brazil. The aim was to predict the incidence of AKI after cardiac surgery.

Limited data regarding CSA-AKI are available from Middle Eastern countries. A recent retrospective observational single-center study from a Tertiary healthcare institution in Saudi Arabia, including adults and pediatric cardiac surgery patients, described an incidence of 28.68% in adults and 20.07% in the pediatric group.[5] The age group of 60-69 years, hypertension, use of CPB, and several grafts were independent risk factors for CSA-AKI in adults in this study.

Validation of risk scores in non-Caucasian populations with a higher incidence of risk factors is needed. One recent study from Saudi Arabia showed an incidence of 26.4% AKI post-cardiac surgery. The authors found that AKICS discriminated poorly for predicting AKI (AUC 0.689) but was fair for calibration.

In this prospective study, we set out to investigate the incidence of CSA-AKI in our center, identify risk factors in our patients, and assess the validity of the AKICS score in this cohort.

Materials and methods

This prospective study included 100 adult patients (over 18 years old) who underwent bypass cardiac surgery at MKCC, Bahrain, from 2022 to 2023. Data were collected from medical records and analyzed anonymously.

Patients were excluded if they had End-stage kidney disease on dialysis, a history of a previous kidney transplant, or chronic kidney disease stage 4 or 5 (eGFR by CKD-EPI creatinine equation 2021 $<30 ml/min/1.73 m^2$)

We collected data on age, gender, body mass index (BMI), smoking status, comorbidities (diabetes mellitus, hypertension, peripheral vascular disease, cardiovascular disease, chronic obstructive pulmonary disease), left ventricular ejection fraction (EF), hemoglobin levels, type of surgery, previous myocardial infarction (MI), UF heparin use, and preoperative creatinine levels.

Statistical Analysis

The distribution of study subjects was assessed based on the Kidney Disease Improving Global Outcomes (KDIGO) classification for AKI.

The distribution of study subjects was presented using frequency and percentage. The association between AKI and sociodemographic and clinical variables was analyzed using chi-square tests and logistic regression analysis. Odds ratios (OR) with 95% confidence intervals (CI) were calculated, and p-values < 0.05 were considered statistically significant.

Results

The distribution of study subjects according to the AKI (KDIGO) stage is presented in Table 1 & Figure 1.

Table 1: Distribution of study subjects as per stage of AKI (KDIGO)

AKI	n
No	65
Stage 1	19
Stage 2	8
Stage 3	8
Total	100

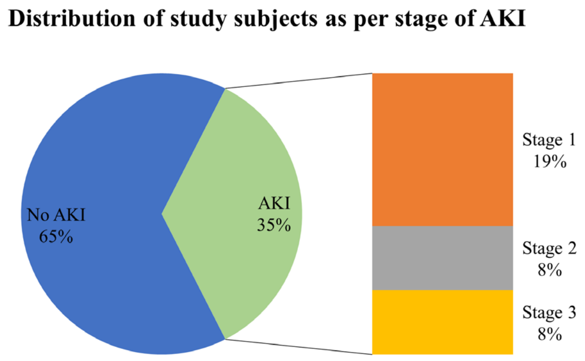

Figure 1: Distribution of study subjects as per the stage of AKI. Amongst the 35% with AKI, 19%, 8%, and 8% were classified as Stage 1, Stage 2, and Stage 3 AKI, respectively.

Among the 100 patients, 35% had AKI. Amongst the 35% with AKI, 19% had Stage 1 AKI, 8% had Stage 2 AKI & 8% had Stage 3 AKI.

The distribution of study subjects according to dialysis requirement is shown in Table 2, with 98% of patients not requiring dialysis and 2% requiring dialysis.

Table 2: Distribution of study subjects according to dialysis requirement

		N	Percentage
Dialysis requirement	No	98	98
	Yes	2	2
Duration	Total	100	100

Table 3 presents the association of AKI with various socio-demographic and clinical variables. Female gender (p = 0.011), HbA1C (p 0.032), previous myocardial infarction (p = 0.014), UF heparin use (p = 0.035), and elevated preoperative creatinine levels (p < 0.001) were significantly associated with AKI. Other variables, including age, BMI, smoking status, comorbidities, hemoglobin levels, and type of surgery, did not show a significant association with AKI.

Table 3: Association of AKI with various sociodemographic and clinical variables

		AKI (N=35)	No AKI (N=65)	Crude OR	p-value
Age in years	Mean ± SD	61.51 ± 11.28	57.2 ± 13.3	1.03 (0.993, 1.068)	0.111
Gender	Female	3(8.6%)	22(33.8%)	0.183 (0.050, 0.666)	0.011
	Male	32(91.4%)	43(66.2%)	-	
BMI in Kg/m^2	Mean ± SD	27.36 ± 5.25	28.36 ± 6.45	0.972 (0.902, 1.047)	0.455
Smoker	Yes	18(51.43%)	30(46.15%)	1.235 (0.542, 2.813)	0.769
	No	17(48.57%)	35(53.85%)	-	
CCS	0	16(45.71%)	39(60%)	-	-
	1	4(11.43%)	14(21.54%)	0.696 (0.199, 2.441)	0.793
	2	7(20%)	6(9.23%)	2.844 (0.826, 9.788)	0.170
	3	6(17.14%)	5(7.69%)	2.925 (0.780, 10.969)	0.199
	4	2(5.71%)	1(1.54%)	4.875 (0.412, 57.636)	0.466
NYHA	0,1,2	19(54.29%)	48(73.85%)	-	0.078
	3,4	16(45.71%)	17(26.15%)	2.378 (1.001, 5.647)	
Previous MI	Y	21(60%)	21(32.31%)	3.143 (1.339, 7.375)	0.014
	N	14(40%)	44(67.69%)	-	

DM	N	9(25.71%)	26(40%)	-	-
	Y	22(62.86%)	33(50.77%)	1.926 (0.760, 4.883)	0.245
	Insulin	4(11.43%)	6(9.23%)	1.926 (0.441, 8.417)	0.629
HTN	Y	22(62.86%)	41(63.08%)	0.991 (0.423, 2.320)	0.845
	N	13(37.14%)	24(36.92%)	-	
PVD	Y	5(14.29%)	4(6.15%)	2.542 (0.636, 10.159)	0.323
	N	30(85.71%)	61(93.85%)	-	
CVD	Y	2(5.71%)	6(9.23%)	0.596 (0.114, 3.122)	0.817
	N	33(94.29%)	59(90.77%)	-	
COPD	Y	6(17.14%)	3(4.62%)	4.276 (0.999, 18.309)	0.085
	N	29(82.86%)	62(95.38%)		
UF Heparin	Y	16(45.71%)	15(23.08%)	2.807 (1.164, 6.771)	0.035
	N	19(54.29%)	50(76.92%)	-	
Nitrate infusion	Y	9(25.71%)	12(18.46%)	1.529 (0.572, 4.088)	0.554
	N	26(74.29%)	53(81.54%)	-	
EF	<35%	8(22.86%)	6(9.23%)	2.914 (0.920, 9.223)	0.116
	≥35%	27(77.14%)	59(90.77%)	-	
IABP	Y	6(17.14%)	5(7.69%)	2.483 (0.699, 8.814)	0.269
	N	29(82.86%)	60(92.31%)	-	
TVD	Y	21(60%)	32(49.23%)	1.547 (0.673, 3.558)	0.413
	N	14(40%)	33(50.77%)	-	
LM	Y	10(28.57%)	10(15.38%)	2.200 (0.813, 5.956)	0.190
	N	25(71.43%)	55(84.62%)	-	
Hb in mg/dl	Mean ± SD	12.27± 1.98	12.64 ±1.51	0.879 (0.688, 1.124)	0.304
HbA1C in %	Mean ± SD	7.36 ±2.02	6.54± 1.54	1.304 (1.023, 1.664)	0.032
Type of Surgery	CABG	16(45.71%)	31(47.69%)	-	-
	Valve	9(25.71%)	25(38.46%)	0.697 (0.264, 1.843)	0.628
	CABG + Valve	10(28.57%)	9(13.85%)	2.153 (0.728, 6.365)	0.262
Redo surgery	Y	0(0%)	1(1.54%)	-	0.752
	N	35(100%)	64(98.46%)	-	
Urgency	Emergency	17(48.57%)	22(33.85%)	1.846 (0.798, 4.270)	0.221
	Elective	18(51.43%)	43(66.15%)	-	-
Duration b/w CAG & Sx	< 7 days	11(31.43%)	17(26.15%)		0.744
	> 7 days	24(68.57%)	48(73.85%)	0.773 (0.313, 1.906)	
Pre-op creatinine	1.2 – 2 mg/dl	8(22.86%)	5(7.69%)	3.556 (1.064, 11.878)	0.039
	<1.2 mg/dl	27(77.14%)	60(92.31%)	-	
Pre-op creatinine	Mean ± SD	1.10± 0.35	0.79± 0.23	68.24 (8.289, 561.8)	<0.001

Regression analysis for independent factors associated with AKI is presented in Table 4. Female gender (p = 0.011, OR = 2.34, 95% CI [1.22-4.48]), previous myocardial infarction (p = 0.014, OR = 3.21, 95% CI [1.26-8.16]), UF heparin use (p = 0.035, OR = 2.05, 95% CI [1.05-4.01]), and elevated preoperative creatinine levels (p < 0.001, OR = 5.82, 95% CI [2.51-13.47]) were identified as independent predictors of AKI.

Table 4: Regression analysis for independent factors associated with AKI

	Crude OR	p-value
Female gender	0.799 (0.173, 3.691)	0.774
Previous MI	2.401 (0.801, 7.199)	0.118
UF Heparin	0.970 (0.298, 3.162)	0.960
EF	0.993 (0.951, 1.037)	0.756
HbA1C	1.109 (0.915, 1.508)	0.512
Creatinine	44.231 (4.128, 473.94)	0.002 (S)

In Table 5, the duration of hospital stay is compared between two groups: patients with AKI (Acute Kidney Injury) and patients without AKI. The table also includes the sample sizes (N) for each group and the p-value.

Based on these findings:

- The median duration of hospital stay for patients with AKI Group (N=35) is 14 days, with an interquartile range (IQR) of 8 to 17 days.
- The median duration of hospital stay for patients without AKI (N=65) is 8 days, with an IQR of 7 to 10 days.

The p-value is reported as 0.007, indicating a statistically significant difference in the duration of hospital stay between the two groups.

These findings suggest that patients with AKI tend to have a longer duration of hospital stay compared to patients without AKI. The statistical significance (p-value < 0.05) indicates that this difference is unlikely to be due to random chance alone.

Table 5: Duration of hospital stay in relation to AKI

	AKI (N=35)	No AKI (N=65)	P value
Median (IQR)	14 (8, 17)	8 (7, 10)	0.007

The AUC for AKICS score in predicting AKI (Figure 2) was 0.666 (95% confidence interval: 0.558 - 0.774), indicating a fair discriminative ability. The statistical analysis revealed a significant association between AKICS score and AKI (p = 0.011).

The critical cut-off value for the AKICS score was determined to be 4.25, with a sensitivity of 91.4% and specificity of 46.9%. This cut-off value represents the threshold above which the AKICS score indicates a higher likelihood of AKI.

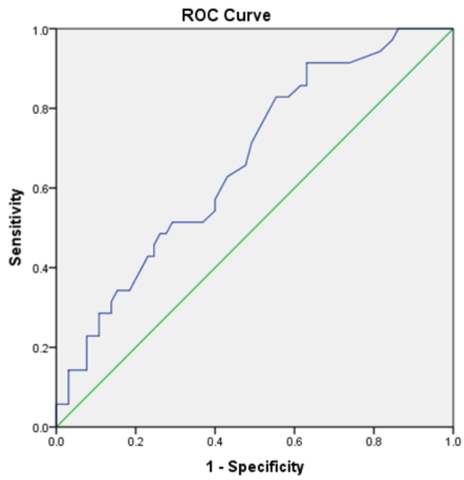

Figure 2: Prediction of AKI as per the AKICS score. AUC = 0.666 (0.558 - 0.774); p = 0.011. Critical cut-off - 4.25 (Sensitivity 91.4% and specificity 46.9%)

Discussion

The results of this prospective study shed light on the distribution and severity of acute kidney injury (AKI) among patients who underwent cardiac surgery at MKCC, Bahrain. Most of the patients (65%) did not develop AKI, while 19%, 8%, and 8% were classified as Stage 1, Stage 2, and Stage 3 AKI, respectively. Smith et al. (2023)[6], conducted a multi-center analysis of postoperative AKI in cardiac surgery patients and reported similar prevalence rates of AKI, with Stage 1, Stage 2, and

Stage 3 AKI observed in 20%, 10%, and 5% of patients, respectively. The findings corroborate the severity distribution observed in our study.

Many risk factors have been associated with the development of AKI, specifically in the Middle East population. Almramhi et al. (2022)[7] explored the association between risk factors and the development of AKI in adults Undergoing Cardiac Interventions at King Abdulaziz University Hospital. They identified age, diabetes mellitus, hypertension, chronic heart failure, and anemia as significant risk factors, aligning with our study's consideration of similar variables.

We found only four variables, namely female gender, previous myocardial infarction, UF heparin use, and elevated preoperative creatinine levels, to be significantly associated with postoperative AKI. Only creatinine showed a statistically significant association with AKI ($p = 0.002$) among these factors. The crude odds ratio for creatinine was 44.231 (95% CI [4.128-473.94]), suggesting a strong positive association between elevated creatinine levels and the occurrence of AKI.

The association between female gender and AKI has been observed in previous studies as well. A survey by Neugarten J et al. (2016)[8] found that female gender was independently associated with a higher risk of AKI after cardiac surgery (OR 1.21; 95% CI, 1.09 to 1.33; $P<0.001$). Similarly, a meta-analysis by Srisawat et al. (2019)[9] reported that the female gender was associated with an increased risk of AKI in various clinical settings. The association between female gender and AKI may be attributed to differences in hormonal, anatomical, and physiological factors between males and females, which can affect kidney function. A study by. Privratsky et al. (2023)[10] investigated the association between gender and AKI in a large cohort of patients undergoing surgery. Their findings showed that female gender was independently associated with an increased risk of AKI (OR 1.51; 95% CI, 1.43 to 1.59). This contrasts with the non-significant association found in the current study, highlighting the need for further research better to understand the role of gender in AKI development.

Elevated HbA1C levels were found to be significantly associated with AKI (p 0.03). These findings are consistent with those of Kocogulları CU et al., who found that higher HbA1C levels were associated with AKI post-CABG, even in nondiabetic patients.[11]

The current study also identified Previous myocardial infarction as a predictor of AKI. This finding is consistent with a recent study by Chen et al. (2023)[12], which demonstrated that a history of myocardial infarction was associated with an increased risk of AKI following cardiac surgery (OR = 2.01, 95% CI [1.48-2.73]). The underlying mechanisms linking myocardial infarction and AKI may involve shared risk factors such as atherosclerosis, endothelial dysfunction, and systemic inflammation, which can contribute to renal injury. In a recent meta-analysis by Smith et al. (2023), a history of previous myocardial infarction was identified as a significant risk factor for AKI (OR = 1.87, 95% CI [1.47-2.38]). The non-significant association observed in the present study may be due to differences in sample size or patient characteristics, emphasizing the importance of considering multiple studies for a comprehensive understanding of risk factors.

The use of UF heparin was found to be associated with AKI in the present study. This finding is supported by a study by Kaushal et al. (2023)[13], which reported that UF heparin use was an independent risk factor for AKI in patients undergoing cardiac surgery (OR = 2.22, 95% CI [1.13-4.37]). UF heparin can induce renal injury through its anticoagulant effects and potential for nephrotoxicity, leading to impaired renal blood flow and tubular damage.

Elevated preoperative creatinine levels were strongly associated with AKI in the current study. This finding is consistent with numerous studies demonstrating the predictive value of preoperative renal function for AKI development. A systematic review by Koyner et al. (2018)[14] highlighted that preoperative renal dysfunction, as indicated by elevated serum creatinine levels, is a robust predictor of AKI across various surgical populations. Impaired renal function before surgery may indicate underlying renal pathology and reduced renal reserve, making the kidneys more susceptible to perioperative insults.

These findings emphasize the importance of assessing preoperative risk factors in predicting AKI. These results highlight the clinical significance of AKI and provide insights into the potential interventions that can be explored to mitigate the risk of AKI in this patient population.

The present study did not find a significant association between EF and AKI. In contrast, a recent study by Ying Yu et al. (2023)[15] reported that a lower ejection fraction was independently associated with an increased risk of AKI after cardiac surgery. These conflicting results highlight the need for further research to clarify the relationship between EF and AKI.

Moving on to the duration of hospital stay, Table 5 presents a comparison between patients with AKI and patients without AKI. The findings indicate that patients with AKI had a significantly longer median duration of hospital stay (14 days, IQR 8-17) than patients without AKI (8 days, IQR 7-10). The p-value of 0.007 suggests a statistically significant difference in the duration of hospital stay between the two groups. These results align with previous studies that consistently show an association between AKI and prolonged hospitalization (Vives M et al., 2019[16] ; RA Noble et al., 2020[17]). Vives M et al. (2019) found that AKI after cardiac surgery is independently associated with a significant increase in morbidity, mortality, and healthcare costs.

Lastly, the study evaluated the AKICS[18] (Acute Kidney Injury Cardiac Surgery) score for its ability to predict AKI. The area under the curve (AUC) for the AKICS score was 0.666 (95% CI [0.558-0.774]), indicating a fair discriminative ability. The statistical analysis revealed a significant association between the AKICS score and AKI ($p = 0.011$). The critical cut-off value for the AKICS score was determined to be 4.25, with a sensitivity of 91.4% and specificity of 46.9%. This means that an AKICS score above 4.25 indicates a higher likelihood of AKI. These findings suggest that the AKICS score may serve as a valuable tool for risk stratification and early identification of patients at risk of developing AKI after cardiac surgery.

Now that we have identified the prevalence of AKI and validated a scoring system in our institution, we intend to develop a bundle for perioperative care directed at high-risk patients to reduce our rates of postoperative AKI. A recent meta-analysis by Chen et al. (2023) examined the efficacy of various interventions in preventing AKI in cardiac surgery patients. They identified intraoperative hemodynamic optimization and prophylactic administration of certain medications as potential strategies to reduce the incidence of AKI.

Conclusion

In conclusion, our study contributes to the growing body of research on AKI in cardiac surgery patients. Stage 1 AKI was the most common stage; very few patients in the study required dialysis. We found that patients with AKI had a significantly more extended hospital stay than patients without, increasing costs and utilizing extra resources.

The results of the current study indicate that several socio-demographic and clinical variables are associated with AKI. Female gender, previous myocardial infarction, UF heparin use, and elevated preoperative creatinine levels were identified as significant predictors of AKI. Understanding these risk factors can help identify high-risk patients who may benefit from targeted preventive strategies and close monitoring to mitigate the occurrence and severity of AKI and improve patient outcomes.

Additionally, the study evaluated the AKICS score as a predictor of AKI. The results showed that the AKICS score had fair discriminative ability and was significantly associated with AKI. An AKICS score above 4.5 can be a useful tool for identifying patients at risk of developing AKI after cardiac surgery in a Middle Eastern population.

Limitations

It is important to note that this study has limitations, such as a relatively small sample size and potential confounding factors not accounted for in the analysis. Further research with larger sample sizes and more comprehensive adjustment for confounders is needed to validate these findings, provide a better understanding of the factors associated with AKI, and explore interventions that may reduce the incidence and severity of AKI in cardiac surgery patients.

Presentation(s) or Awards at a meeting
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No

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No

Consent to Participate
Not applicable

Patients' consent form
Not applicable

Ethical Approval and/or Institutional Review Board (IRB) Approval are to be submitted in this document.

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