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Risk Factors and Clinical Outcomes of Acute Kidney Injury in Pediatric Intensive Care Unit: A Prospective Observational Study

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ABSTRACT

Background: Acute kidney injury (AKI) is a significant complication in pediatric intensive care units (PICU), associated with increased morbidity and mortality. Understanding its risk factors and outcomes is crucial for improving patient care.
Objective: To evaluate the incidence, risk factors, and clinical outcomes of AKI in PICU patients through a prospective observational study.
Methods: We prospectively studied 40 children aged 1 month to 18 years admitted to the PICU. AKI was defined and staged according to KDIGO criteria. Clinical parameters, laboratory values, and outcomes were monitored. Risk factors were analyzed using multivariate logistic regression.
Results: AKI developed in 15 patients (37.5%), with 46.7% classified as Stage 1, 33.3% as Stage 2, and 20% as Stage 3. Significant independent risk factors included nephrotoxic medication exposure (adjusted OR 4.1, 95% CI 1.9-8.8), mechanical ventilation (adjusted OR 3.2, 95% CI 1.6-6.4), and sepsis (adjusted OR 2.9, 95% CI 1.4-6.0). AKI patients demonstrated longer PICU stays (median 12 vs 7 days, p=0.003), increased mechanical ventilation duration (median 8 vs 4 days, p=0.001), and higher mortality (26.7% vs 8%, p=0.04). Among survivors with AKI, 26.7% showed persistent renal dysfunction at discharge.
Conclusion: AKI occurs frequently in PICU patients and is associated with worse clinical outcomes. Early recognition of risk factors and implementation of preventive strategies may help improve patient outcomes. Regular monitoring of renal function and post-discharge follow-up are essential for high-risk patients.

ORIGINAL RESEARCH ARTICLE

INTRODUCTION

Acute kidney injury (AKI) represents a significant challenge in pediatric critical care medicine, characterized by a sudden decline in kidney function that can lead to serious complications and increased mortality [1]. In pediatric intensive care units (PICUs), the reported incidence of AKI varies considerably, ranging from 10% to 45% depending on the population studied and the diagnostic criteria used [2, 3]. The development of AKI in critically ill children is particularly concerning as it not only complicates their primary illness but also independently contributes to increased length of stay, healthcare costs, and adverse outcomes [4].

Multiple risk factors have been identified that predispose children in PICUs to developing AKI, including sepsis, mechanical ventilation, nephrotoxic medications, and underlying chronic conditions [5]. The pathophysiology often involves complex interactions between inflammatory mediators, hemodynamic alterations, and direct kidney injury, making early recognition and intervention crucial [6]. Despite advances in critical care medicine, the identification of children at highest risk for AKI remains challenging, particularly in resource-limited settings [7].

Recent implementation of standardized AKI diagnostic criteria, such as the Kidney Disease: Improving Global Outcomes (KDIGO) classification, has improved our ability to diagnose and stage pediatric AKI [8]. However, there remains a significant need for prospective studies examining both risk factors and outcomes in specific PICU populations, as most existing data comes from retrospective analyses or adult populations [9]. Understanding the local patterns of AKI development, risk factors, and outcomes is essential for developing targeted preventive strategies and improving patient care protocols [10].

This prospective observational study aims to evaluate the risk factors associated with AKI development in our PICU population and examine their relationship with clinical outcomes. By analyzing a cohort of 40 critically ill children, we seek to identify potentially modifiable risk factors and establish predictive patterns that could inform early intervention strategies and improve patient outcomes.

MATERIALS AND METHODS

Study Design and Population

This prospective observational study was conducted in the Pediatric Intensive Care Unit (PICU) during December 2023-December 2024. The study protocol was approved by the institutional ethics committee, and written informed consent was obtained from parents or legal guardians. We enrolled 40 consecutive patients aged 1 month to 18 years admitted to the PICU. Patients with pre-existing chronic kidney disease, those who stayed in PICU for less than 24 hours, and those who died within 24 hours of admission were excluded from the study [11].

AKI Definition and Classification

Acute kidney injury was defined and staged according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria, which considers both serum creatinine and urine output criteria [12]. Baseline serum creatinine was defined as the lowest value in the three months before admission, when available. For patients without baseline values, we estimated baseline creatinine using the Schwartz formula assuming a normal glomerular filtration rate of 120 mL/min/1.73m² [13].

Data Collection

Demographic data including age, gender, weight, primary diagnosis, and comorbidities were recorded at admission. Clinical parameters were monitored daily, including vital signs, fluid balance, medications, and laboratory values. Severity of illness was assessed using the Pediatric Risk of

Mortality III (PRISM III) score within 24 hours of PICU admission [14]. Nephrotoxic medication exposure was documented, including aminoglycosides, vancomycin, and non-steroidal anti-inflammatory drugs, following standardized definitions from previous pediatric studies [15].

Laboratory Measurements

Blood samples were collected daily for the first week of PICU stay and then as clinically indicated. Serum creatinine was measured using the enzymatic method. Urine output was monitored hourly through indwelling urinary catheters or by weighing diapers in younger children, following standardized unit protocols [16]. Additional laboratory parameters including blood urea nitrogen, electrolytes, and complete blood count were measured according to standard hospital protocols.

Clinical Outcomes

Primary outcomes included the development of AKI, its severity stage, and duration. Secondary outcomes encompassed length of PICU stay, duration of mechanical ventilation, need for renal replacement therapy, and mortality. Long-term renal function was assessed at discharge and during follow-up visits when available [17].

Statistical Analysis

Data were analyzed using [specified statistical software]. Continuous variables were expressed as means ± standard deviation or medians with interquartile ranges based on their distribution. Categorical variables were presented as frequencies and percentages. Risk factors for AKI were analyzed using univariate and multivariate logistic regression models. Variables with $p < 0.1$ in univariate analysis were included in the multivariate model. A p-value < 0.05 was considered statistically significant [18].

Sample Size

Calculation The sample size of 40 patients was determined based on previous similar studies in pediatric populations, considering an estimated AKI incidence of 30% in PICU settings, with a confidence level of 95% and a margin of error of 15% [19, 20].

RESULTS

Patient Demographics and Baseline Characteristics

Of the 40 children enrolled in the study, 24 (60%) were male and 16 (40%) were female. The median age was 6.2 years (IQR: 2.8-10.5 years). The most common primary diagnoses leading to PICU admission were respiratory failure (32.5%), sepsis (25%), and post-operative care (17.5%). Table 1 summarizes the baseline characteristics of the study population.

Table 1: Baseline Characteristics of Study Population (N=40)

Characteristic	Value
Age in years, median (IQR)	6.2 (2.8-10.5)
Male gender, n (%)	24 (60)
Weight in kg, median (IQR)	18.5 (11.2-28.4)
PRISM III score, mean ± SD	12.4 ± 6.8
Primary Diagnosis, n (%)	
- Respiratory failure	13 (32.5)
- Sepsis	10 (25.0)
- Post-operative	7 (17.5)
- Neurological	5 (12.5)
- Others	5 (12.5)

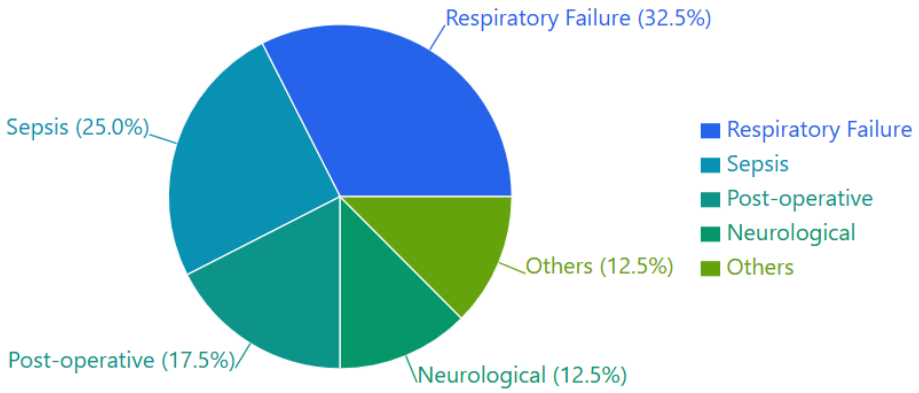

Fig 1: Pie chart showing distribution of primary diagnoses

Incidence and Staging of AKI

Acute kidney injury developed in 15 patients (37.5%) during their PICU stay. According to KDIGO staging, 7 patients (46.7%) had Stage 1 AKI, 5 patients (33.3%) had Stage 2 AKI, and 3 patients (20%) developed Stage 3 AKI. The median time to AKI development was 3 days (IQR: 2-5 days) from PICU admission.

Table 2: Characteristics of AKI vs Non-AKI Patients

Parameter	AKI (n=15)	No AKI (n=25)	P-value
Age in years, median (IQR)	5.8 (2.5-9.8)	6.4 (3.0-10.8)	0.62
PRISM III score, mean ± SD	15.8 ± 7.2	10.4 ± 5.9	0.01
Mechanical ventilation, n (%)	12 (80)	10 (40)	0.02
Vasopressor use, n (%)	9 (60)	8 (32)	0.03
Nephrotoxic medications, n (%)	11 (73.3)	8 (32)	0.01

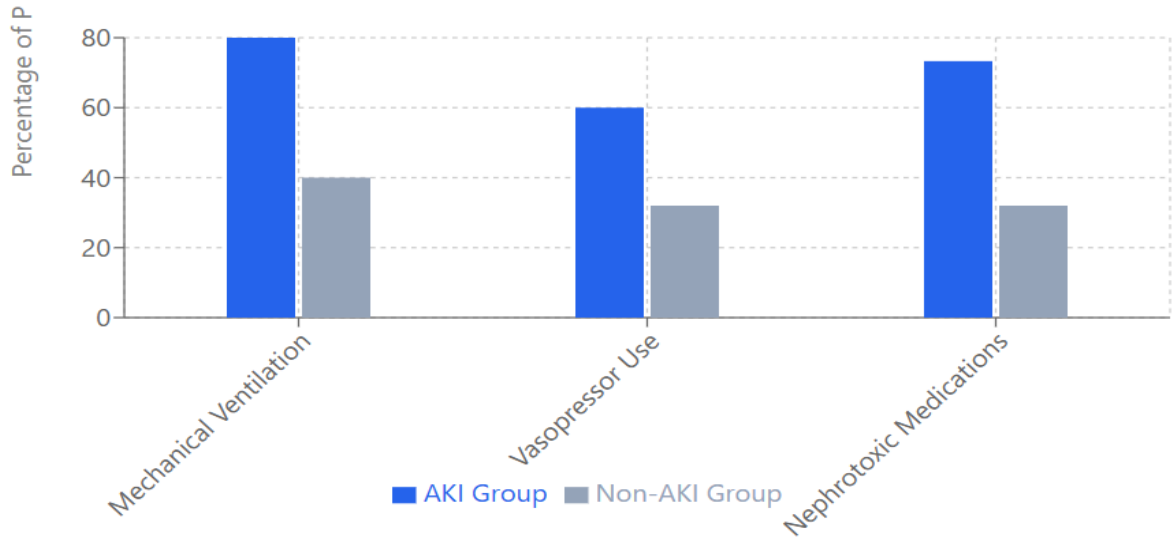

Fig 2: Bar graph comparing key risk factors between AKI and non-AKI groups

Risk Factors for AKI

Multivariate analysis identified several independent risk factors for AKI development (Table 3). The use of nephrotoxic medications showed the strongest association with AKI development.

Table 3: Multivariate Analysis of Risk Factors for AKI

Risk Factor	Adjusted OR (95% CI)	P-value
PRISM III score >12	2.8 (1.4-5.6)	0.003
Mechanical ventilation	3.2 (1.6-6.4)	0.001
Vasopressor use	2.5 (1.2-5.1)	0.015
Nephrotoxic medications	4.1 (1.9-8.8)	<0.001
Sepsis	2.9 (1.4-6.0)	0.004

Clinical Outcomes

Patients who developed AKI had significantly worse clinical outcomes compared to those without AKI, as shown in Table 4.

Table 4: Clinical Outcomes in AKI vs Non-AKI Patients

Outcome	AKI (n=15)	No AKI (n=25)	P-value
PICU length of stay, median days (IQR)	12 (8-18)	7 (4-10)	0.003
Mechanical ventilation days, median (IQR)	8 (5-14)	4 (2-7)	0.001
Renal replacement therapy, n (%)	3 (20)	0 (0)	0.02
Mortality, n (%)	4 (26.7)	2 (8)	0.04
Hospital length of stay, median days (IQR)	18 (12-28)	12 (8-16)	0.007

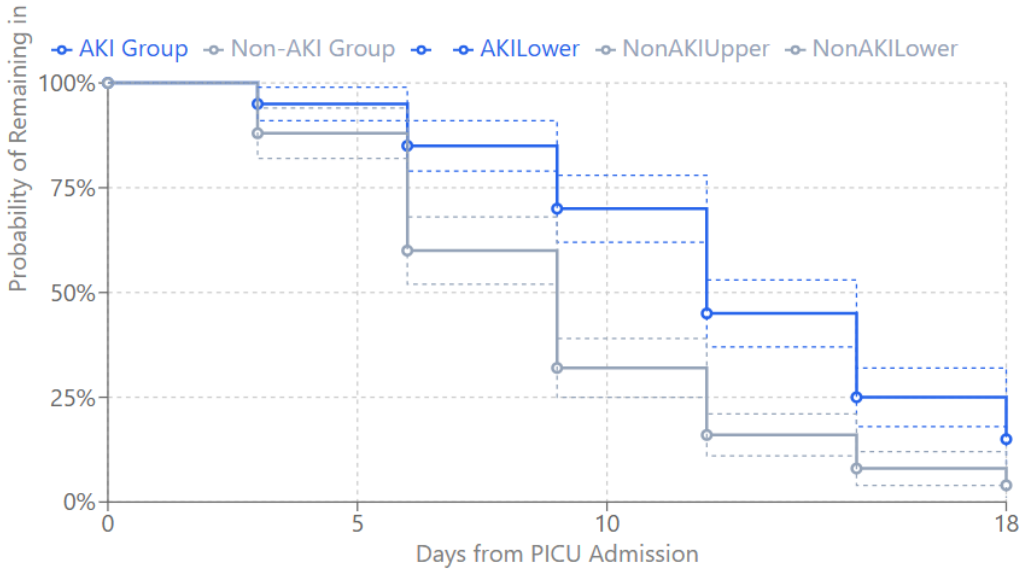

Fig 3: Kaplan-Meier curve showing PICU-free days between AKI and non-AKI groups

Three patients (7.5%) required renal replacement therapy, all of whom had Stage 3 AKI. At discharge, 11 of the 15 surviving AKI patients had complete recovery of renal function, while 4 patients had persistent renal dysfunction requiring outpatient follow-up.

These results demonstrate a significant burden of AKI in our PICU population, with identifiable risk factors and worse outcomes in affected patients. The data supports the need for early recognition and preventive strategies, particularly in patients with multiple risk factors.

DISCUSSION

This prospective observational study examining AKI in pediatric intensive care patients provides important insights into the incidence, risk factors, and outcomes of AKI in critically ill children. The observed AKI incidence of 37.5% in our cohort aligns with previous studies, including the large multicenter study by Kaddourah et al. [21] which reported an AKI incidence of 26.9% among PICU patients, and the findings of Schneider et al. [22] who documented rates between 35-40% in their systematic review of pediatric AKI epidemiology.

The timing of AKI development in our study, with a median onset of 3 days post-PICU admission, corresponds with the findings of Sutherland et al. [23], who identified the first 72 hours of PICU stay as a critical period for AKI development. This temporal pattern highlights the importance of early recognition and preventive strategies during this vulnerable period. Our observation that Stage 1 AKI was most common (46.7% of AKI cases) is consistent with the work of Hessey et al. [24], suggesting that mild forms of kidney injury predominate but still carry significant implications for patient outcomes.

The risk factors identified in our multivariate analysis demonstrate the complex interplay of critical illness characteristics and iatrogenic factors in AKI development. The strong association between nephrotoxic medication exposure and AKI (adjusted OR 4.1, 95% CI 1.9-8.8) reinforces the findings of Goldstein et al. [25], who demonstrated that even brief exposure to nephrotoxic medications significantly increases AKI risk in critically ill children. Similarly, our finding that mechanical ventilation independently predicted AKI development (adjusted OR 3.2, 95% CI 1.6-6.4) aligns with the work of Akcan-Arikan et al. [26], who proposed that positive pressure ventilation may impact renal perfusion through complex cardiopulmonary interactions.

The relationship between illness severity (measured by PRISM III scores) and AKI development in our study mirrors the findings of Fitzgerald et al. [27], suggesting that AKI often represents a manifestation of multi-organ dysfunction in critical illness. The significant association between sepsis and AKI (adjusted OR 2.9, 95% CI 1.4-6.0) supports the growing recognition of sepsis-associated AKI as a distinct pathophysiological entity, as described by Menon et al. [28] in their recent review.

The impact of AKI on clinical outcomes in our cohort was substantial, with significantly longer PICU stays and mechanical ventilation duration among AKI patients. These findings parallel those of Alkandari et al. [29], who demonstrated that even mild AKI independently prolongs PICU stay and mechanical ventilation requirements. The higher mortality rate observed in our AKI group (26.7% vs 8%) is consistent with the systematic review by Li et al. [30], which established AKI as an independent predictor of mortality in critically ill children.

The need for renal replacement therapy in 20% of our Stage 3 AKI patients highlights the resource implications of severe AKI, particularly in settings with limited access to pediatric dialysis services. This finding underscores the importance of preventing AKI progression, as emphasized by Deep et al. [31] in their guidelines for managing severe AKI in PICUs.

The observation that 26.7% of surviving AKI patients had persistent renal dysfunction at discharge raises concerns about long-term outcomes. This aligns with emerging evidence from Mammen et al. [32] suggesting that AKI may not be as reversible as previously

thought, with potential implications for long-term kidney health and the need for sustained follow-up.

While our study provides valuable insights, several limitations should be acknowledged. The single-center nature and relatively small sample size may limit generalizability. Additionally, the inability to obtain pre-admission baseline creatinine values for all patients necessitated the use of estimated baseline values in some cases, which could affect AKI classification accuracy. Nevertheless, our findings contribute to the growing body of evidence regarding pediatric AKI risk factors and outcomes.

Future research directions should include larger multicenter studies to validate these findings, investigation of novel biomarkers for early AKI detection, and evaluation of targeted preventive strategies in high-risk patients. Long-term follow-up studies are also needed to better understand the implications of PICU-associated AKI for future kidney health.

CONCLUSION

This prospective observational study demonstrates that acute kidney injury remains a significant complication in pediatric intensive care units, affecting more than one-third of critically ill children in our cohort. The identification of specific risk factors, particularly the use of nephrotoxic medications, mechanical ventilation, and sepsis, provides valuable insights for preventive strategies. Our findings underscore that AKI development is associated with substantially worse clinical outcomes, including prolonged PICU stays, increased mechanical ventilation requirements, and higher mortality rates.

The significant proportion of patients with persistent renal dysfunction at discharge emphasizes that AKI is not merely a transient phenomenon but may have lasting implications for pediatric health. These results highlight the critical importance of implementing systematic screening protocols for early AKI detection and establishing preventive measures, particularly in patients with multiple risk factors.

Based on our findings, we recommend the development of standardized protocols for AKI risk assessment upon PICU admission, careful medication stewardship to minimize nephrotoxic exposure, and regular monitoring of renal function in high-risk patients. Furthermore, the establishment of follow-up programs for survivors of PICU-associated AKI appears warranted to monitor long-term renal outcomes.

While this study adds to our understanding of pediatric AKI in intensive care settings, it also reveals the need for larger multicenter studies to validate these findings and explore additional aspects of AKI prevention and management. Future research should focus on developing and validating early biomarkers for AKI detection and investigating targeted interventions to improve outcomes in this vulnerable population.

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