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Etiology and Outcome of Acute Kidney Injury in Children: The South Asian Experience With Special Reference to Bangladesh

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ABSTRACT

Background and Aim: Pediatric acute kidney injury (AKI)'s incidence, etiology, and outcomes are very diverse and influenced by factors, such as age, location, and clinical situation. Emphasizing regional epidemiology and its underlying causes is crucial for improving the identification and management of this insidious issue.

Methods: This retrospective study was done at the Pediatric Nephrology Department of Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, a developing country in South Asia. It included AKI patients aged 28 days to 18 years who attended outpatient and inpatient departments between July 1, 2022, and August 31, 2024.

Results: In a 24-month span, 356(27.05%) instances of AKI were detected, with 5 to 15 years (55.06%) being the most prevalent age range. The etiology of AKI was identified to be prerenal in 154 cases (46.26%), renal in 170 instances (47.75%), and postrenal in 32 cases (8.98%). Of the total number of patients, 290(81.46%) were managed with conservative treatment, while 20(5.62%) required hemodialysis and 46(12.92%) required peritoneal dialysis. Over a three-month period, 302 children (84.83%) remained alive, with 17(4.78%) developing CKD, 22(6.18%) developing end-stage renal disease (ESRD), and 15(4.21%) passed away ($P<0.0001$). The presence of anuria, volume overload, and primary renal disease were identified as significant risk factors for beginning renal replacement therapy (hemodialysis and peritoneal dialysis).

Conclusion: Pediatric AKI is mainly caused by gastroenteritis, sepsis, and rapidly progressive glomerulonephritis (RPGN), which recover well at a single tertiary care center. Oliguria/anuria, anemia, volume overload, failure (pRIFLE category) at presentation, and dialysis necessity were correlated with unfavorable renal outcomes.

Keywords: Acute kidney injury(AKI), Pediatrics, Epidemiology, Outcome

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Introduction

Acute kidney injury (AKI) refers to any sudden decline in kidney function, which can be reversible if detected early. It can be community-acquired, resulting from an injury or infection before hospital admission, or can be hospital-acquired, arising as a complication of hospital admission [1]. The prevalence of AKI is thought to be higher in developing countries than in developed countries, notwithstanding the dearth of high-quality data on the epidemiology of AKI in developing nations [1, 2]. According to estimates, there are up to 13.3 million instances of AKI worldwide every year, 11.3 million of which occur in low- and middle-income nations and result in up to 1.4 million fatalities [3]. Furthermore, it is estimated that 60% of individuals who survive AKI may experience ongoing renal abnormalities, such as proteinuria, hypertension, and reduced glomerular filtration rate (GFR) [1]. Additionally, AKI-related issues are the cause of up to 3% of hospital admissions in low-resource settings [3]. The frequency, cause, and prognosis of pediatric AKI varies based on age, geographic location, and clinical context. In developed areas, 7% to 18% of hospital inpatients each year report having acquired AKI, which is five to ten times more common in hospitals than in the community [4, 5]. On the other hand, AKI commonly occurs in communities in less developed countries [4]. However, limited information exists addressing the epidemiology and causes of AKI in low-resource countries. Also, healthcare resources to diagnose and manage AKI are often limited, with a lack of appropriate medications, equipment, and trained personnel. Regional epidemiology and causes should be highlighted to enhance early AKI recognition and care. Therefore, this study was designed to determine the etiology, clinical profile, and short-term outcomes of pediatric patients presenting with AKI from low-resource, developing countries, like Bangladesh.

Materials and Methods

This retrospective study was done at the Pediatric Nephrology Department of Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh (a developing country in South Asia), a tertiary care facility serving as a referral center for several regional hospitals nationwide.

Data of all the children who attended both outpatient and inpatient departments between July 1, 2022, and August 31, 2024 were reviewed from a departmental electronic database. Permission from the institutional review board was taken. All the patients aged 28 days to 18 years and diagnosed as cases of acute kidney injury (as per the p-RIFLE definition) were included in the study. We excluded neonates (aged less than 28 days), individuals with documented preexisting chronic kidney disease (CKD) stages 3 to 5, those with congenital anomalies of the kidneys and urinary tract, and patients with incomplete data. Electronic patient files were searched, and relevant data concerning etiology, clinical features, such as hypertension, urine output, features of volume overload, as well as baseline investigations, i.e. complete blood count, urea, creatinine, electrolytes, urinalysis, urine, and blood cultures, and ultrasound of kidneys, ureters, and bladder were obtained. The diagnosis of AKI was based on the pRIFLE (pediatric risk, injury, failure, loss, end-stage renal disease [ESRD]) criteria [6]. Estimated GFR was determined using the modified Schwartz equation [7].

The severity of AKI was evaluated using the pRIFLE criteria with 'R' for risk, 'I' for injury, and 'F' for failure. The etiology of AKI was grouped as prerenal, renal, and postrenal.

All AKI children were treated under institutional guidelines. Dialysis was initiated in the presence of one or more of the following indications: Severe electrolyte disturbances, persistent metabolic acidosis unresponsive to treatment, uremic encephalopathy, fluid overload, and anuria persisting for more than 24 hours. Hemodialysis (HD) was the initial modality of choice. However, peritoneal dialysis (PD) was preferred for children weighing less than 20 kg or those with hemodynamic instability, due to its better tolerability in such cases. Oliguria was defined as urine output of less than 0.5 ml\kg\hr in children and less than 1 ml\kg\hr in infants. Hypervolemia was defined as a positive fluid balance of more than 10% of dry weight. Hyperkalemia was defined as a serum potassium level of more than 5.5 mmol\L. Hypocalcemia was defined as a serum calcium level less than 2 mmol\L. Hyperphosphatemia was defined as a serum phosphate level of more than 1.5 mmol\L. Acidosis was defined as pH less than 7.35 and/or bicarbonate level less than 22 mmol\L. Anemia was defined as the reduction of hemoglobin concentration two standard deviations below the mean, based on age-specific normal level. Hypertension was defined as systolic and diastolic blood pressures greater than the 95th percentile for age, gender, and height. Shock was identified with cold, clammy extremities, feeble or absent peripheral pulses, tachycardia, and systolic blood pressure less than 5th centile for age. Inotropes, such as dopamine, dobutamine, and noradrenaline were used to reverse the shock according to the patient's condition. Anasarca, weight gain, and hypertension were considered features of volume overload.

Follow-up data, including clinical and laboratory parameters, were retrieved from the database at discharge and three months later. Outcomes of AKI were evaluated based on mortality, complete renal recovery, development of CKD, and the necessity for long-term dialysis indicative of progression to ESRD. Renal recovery was defined as 'complete' if serum creatinine normalized to the reference range for that age. CKD was defined as eGFR <60 mL/min/1.73 m^2 or eGFR >60 mL/min/1.73 m^2 with structural damage or persistence of proteinuria for >3 months.

SPSS software, version 26.0 (IBM Corp, Armonk, NY) was employed for data analysis. Qualitative data were expressed as frequency and percentages. Quantitative variables were represented as Mean±SD. The chi-square test compared the outcomes of children as per p-RIFLE criteria considering P<0.05 as significant.

Results

Over 24 months, 1838 patients attended both outpatient and inpatient of the pediatric nephrology department. We excluded 522 patients with CKD, congenital anomalies of kidney and urinary tract, missing information, and age less than 28 days. Finally, the medical information of 1316 patients were reviewed. Among them, 356 (27.05%) were AKI cases, whereas the rest were non-AKI cases (Figure 1). According to the pRIFLE criteria, the majority of children were in the injury category (156 patients, 43.82%), followed by the risk category (135 patients, 37.92%) and the failure category (66 patients, 18.54%) (Figure 1).

Among the 356 children diagnosed with AKI, 220 (61.8%) were male and 136 (38.2%) were female, yielding a male-to-female ratio of 1.6:1. The majority of cases occurred in the 5–15-year age group (55.06%), followed by children aged 1–5 years (29.49%) and infants (9.83%). A significant proportion of patients (213; 59.83%) were from rural areas. Additionally, 299 children (83.99%) were referred from other healthcare facilities (Table 1).

Prerenal etiologies accounted for 154 cases (46.26%) of AKI, followed by intrinsic renal causes in 170 cases (47.75%), and postrenal causes in 32 cases (8.98%) as detailed in Table 2. The most common etiology in prerenal causes was gastroenteritis (n=93, 57.76%) followed by sepsis (n=46, 29.17%). Among the renal causes of AKI, RPGN and nephrotic syndrome were observed in 39(22.94%) and 32(18.82%) cases, respectively. Drug-induced AKI was identified in 33 cases (19.41%). Among the postrenal causes, obstruction was noted in 22 cases (68.75%), while urolithiasis was present in 10 cases (31.25%) (Table 2).

Oliguria/anuria was observed in 189 children (53.09%), and altered sensorium in 86 (24.16%). Inotropic support was required in 35 cases (9.38%). Clinical findings included fluid overload in 147 children (41.29%), shock in 47 children (13.2%), and hypertension in 156 children (43.82%). Leukocytosis was the most common lab abnormality, present in 169 cases (47.47%) (Table 3).

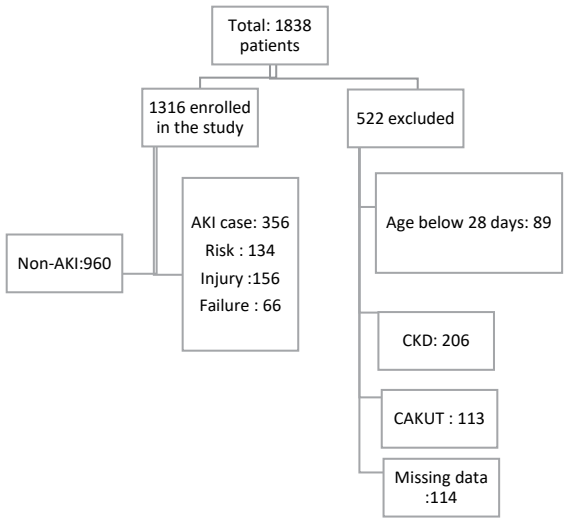

Figure 1. Study flow chart

Abbreviations: AKI: Acute kidney injury; CKD: Chronic kidney disease; CAKUT: Congenital anomalies of kidney and urinary tract.

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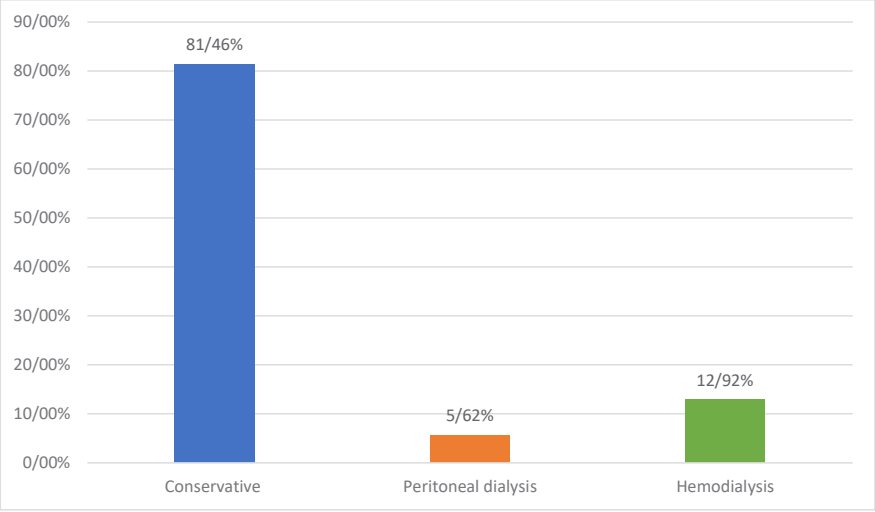

Figure 2. Management required for AKI

There were 290(81.46%) cases that were managed conservatively; 20(5.62%) needed PD, and 46(12.92%) needed HD (Figure 2). At the three-month follow-up period, 302(84.83%) children recovered, 17(4.78%) had CKD, 22(6.18%) developed ESRD, and 15(4.21%) cases died (P<0.0001) (Table 4).

Oliguria/anuria, anemia, volume overload, PRIFLE category failure at presentation, and need for initiation of dialysis were found to have statistically significant (P<0.05) association with unrecovered AKI cases compared to those who recovered, while younger age (<5 years) and hypertension had statistically insignificant association (Table 5).

Significant risk factors for starting dialysis (HD and PD) following logistic regression analysis were the presence of anuria (OR: 3.36; 95% CI, 2.34%, 4.82%; P=0.001), volume overload (OR: 2.55, 95% CI, 1.55%, 4.19%; P=0.001) and the presence of primary renal disease (OR: 6.74; 95% CI, 4.06%, 11.21%; P=0.001) (Table 6).

Discussion

The identification of the occurrence causes, and outcomes of AKI is crucial for implementing effective treatment strategies and facilitating comparisons among epidemiological studies to enhance clinical decision-making. Structurally, there is inadequately reported data from low-resourceful developing countries regarding pediatric AKI. This study provides valuable insights into

Table 1. Demographic characteristics of the study subjects

Characteristics	Category	No. (%)
Age (y)	<1	35(9.83)
	1-5	105(29.49)
	5-15	196(55.06)
	>15	20(5.62)
Gender	Male	220(61.8)
	Female	136(38.2)
Residence	Urban	143(40.17)
	Rural	213(59.83)
Referral from another center		299(83.99)

Table 2. Etiology of acute kidney injuries in children

AKI Types	Etiology	No. (%)
Pre-renal n=154 (46.26%)	Gastroenteritis	93(57.76)
	Sepsis	46(29.17)
	COVID-19	2(1.3)
	DKA	3(1.95)
	DSS	2(1.3)
	Hepatorenal syndrome	1(0.65)
	Tumor lysis syndrome	7(4.55)
Renal n=170 (47.75%)	Drug-induced	33(19.41)
	Post-infectious glomerulonephritis	27(15.88)
	Pyelonephritis	12(7.06)
	Nephrotic syndrome	32(18.82)
	Lupus nephritis	16(9.41)
	RPGN	39(22.94)
	HUS	5(2.94)
	Wasp bite	6(3.53)
Post-renal n=32 (8.98%)	Nephrolithiasis	10(31.25)
	Obstructive uropathy	22(68.75)

Abbreviations: DKA: Diabetes ketoacidosis; DSS: Dengue shock syndrome; RPGN: Rapidly progressive glomerulonephritis; HUS: Hemolytic uremic syndrome.

the range of pediatric AKI cases observed in a major tertiary care referral center in Bangladesh, a developing nation in South Asia.

The incidence of AKI has been reported to range substantially from 10% to 82% in several pediatric studies employing the pRIFLE criteria, or its modifications [8–10]. Our study showed the incidence of AKI to be 27.05%, which is similar to the general incidence of AKI. The inclusion of both hospital- and community-acquired causes in the data is likely to provide a more comprehensive reflection of the incidence.

A significant proportion (43.82%) of the children were classified under the injury category at the time of their presentation. Prior research conducted in low-income countries found a significant proportion of patients with AKI exhibiting severe manifestations of the disease [11]. The shifting landscape may be attributed to the early referral and increased community awareness.

In this study, the majority of patients belonged to the age range of 5-15 years, comprising 196 individuals, which accounted for 55.06% of the total sample. This was followed by another age group of 1-5 years, which had 105 patients, representing 29.49% of the sample. The male to female ratio was 1.6:1. A prior study conducted at the same institution similarly observed a higher occurrence of AKI among older children, with a male-to-female ratio ranging from 1.9:1 to 2:1 [12].

Current literature demonstrates significant regional differences in the etiology of AKI, with community-acquired AKI being more prevalent in developing countries, and hospital-acquired AKI more commonly reported in developed nations. In the present study, prerenal, renal, and postrenal causes accounted for 46.3%,

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Table 3. Clinical and laboratory features of children with acute kidney injury

Clinical profile		No. (%)
Fever		253(71.06)
Shortness of breath		140(39.33)
Oliguria/Anuria		189(53.09)
Altered sensorium		86(24.16)
Loose motion		107(30.05)
Vomiting		169(47.47)
Sign of fluid overload		147(41.29)
Ionotropic support		35(9.38)
Signs of shock		47(13.2)
Hypertension		156(43.82)
Dehydration		188(52.81)
Laboratory profile	Anemia	156(36.52)
	Leukocyte >15000/cm	169(47.47)
	Hyperkalemia	106(29.78)
	Acidosis	71(19.94)

47.8%, and 9% of AKI cases, respectively. Similarly, a prospective study from China identified prerenal causes in 27.7% of AKI cases [13]. Infections have been consistently reported as the predominant cause of AKI in pediatric populations within developing countries [14]. In our study, sepsis and acute gastroenteritis (AGE) emerged as the leading causes of prerenal AKI. Similar observations were reported by Huque et al. [12], likely reflecting the impact of inadequate hygiene and sanitation. Consistent with these findings, studies from other developing countries have also identified sepsis and AGE as the most frequent etiologies of AKI [11, 15]. Among the renal causes of AKI, RPGN was the most common (n=39, 22.94%), found in this study. In our cohort, nephrotoxic medications represented the second most frequent renal cause of AKI, with aminoglycosides, NSAIDs, and calcineurin inhibitors being the principal agents. Among older children and adolescents, nephrotoxic drugs are a well-recognized cause of AKI, with commonly implicated

Table 4. Outcome according to the pRIFLE criteria at three-month follow-up

pRIFLE Categories	No. (%)				P
	Recovered	CKD	ESRD	Death	
Risk (n=134)	132	2	0	0	<0.0001
Injury (n=156)	139	8	5	4	
Failure (n=66)	31	7	17	11	
Total (n=356)	302(84.83)	17(4.78)	22(6.18)	15(4.21)	

CKD: Chronic kidney disease; ESRD: End-stage renal disease.

Note: The chi-square test was used. P<0.05 are significant.

Table 5. Factors effective in the recovery of AKI cases

Variables	No. (%)		P
	Recovered	Unrecovered	
Age <5 years	129(39.4)	21(38.88)	0.22
Oliguria/anuria	141(49.34)	48(89.9)	0.001
Hypertension	127(42)	29 (54.2)	0.14
Anemia	122(40.39)	34(62)	0.01
Volume overload	97(32.12)	50(92.6)	<0.001
pRIFLE category failure	31(10.2)	35(64.81)	0.002
Required dialysis	21(6.95)	45(83.33)	<0.001
Total	302(84.83)	54(15.17)	

AKI: Acute kidney injury.

Note: The chi-square test was used. P<0.05 are significant.

agents, including NSAIDs, antibiotics, antivirals, calcineurin inhibitors, and radiocontrast media [16].

In the present study, fever and leukocytosis (>15 000 cells/mm^3) were found at admission to the hospital in more than two-thirds and one-half of the children, respectively. Oliguria/anuria and dehydration were evident in half of the patients (Table 3).

In a prospective study of over 4000 children admitted to pediatric intensive care units (PICUs) across four (developing) continents, AKI developed in 26.7% of children, of whom 5.8% required renal replacement therapy (RRT) [17], with modalities, including PD, HD, and continuous RRT (CRRT). In the present study, a majority of patients, specifically 81.46%, had conservative management as their treatment approach. The remaining patients needed dialysis, with 12.92% undergoing HD and 5.62% opting for PD. It is noteworthy that the majority of patients in this cohort did not require dialysis (HD and PD), as risk and injury were the prevailing categories of AKI in the present cohort. According to the research done by Huque et al., a significant majority of the patients (91.7%) were similarly subjected to conservative management. Dialysis was reported in a mere three instances [12].

The prognosis of AKI is influenced by several factors, such as the child's age, underlying etiology, and the timing of presentation to healthcare facilities [18]. Studies

Table 6. Risk factors for the initiation of dialysis in children with AKI

Variables	OR (95% CI)	P
Anuria	3.36 (2.34, 4.82)	0.001
Sepsis	1.01 (0.74, 1.39)	0.943
Primary renal disease	6.74 (4.06, 11.21)	0.001
Volume overload	2.55 (1.55, 4.19)	0.001
Shock	0.92 (0.65, 1.31)	0.653
Gender	0.92 (0.65, 1.31)	0.653
Age <5 years	0.89 (0.61, 1.3)	0.546

AKI: Acute kidney injury.

Note: Logistic regression analysis was used. P<0.05 are significant.

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from India have documented mortality rates in children with AKI ranging from 28.5% to 46.3%, while research from sub-Saharan Africa also reported elevated mortality rates, with figures reaching 34% [19, 20]. We documented a significantly low mortality rate (4.21%) in contrast to that reported from India, whereas high recovery and low mortality figures observed in our study are quite similar to that reported from a multicenter study in China [21]. In consonance with Indian studies [20], more than two-thirds of children in our study achieved complete renal recovery at discharge. Among individuals who failed to achieve complete renal recovery, 4.78% and 6.18% developed CKD and ESRD, respectively during the three-month follow-up period. The reported morbidity and mortality rate may be underestimated due to several factors, including the limited duration of follow-up (specifically, a 3-month outcome assessment), which may not capture the true picture occurring in the subsequent months. Additionally, variations in the composition of study cohorts across various studies can contribute to discrepancies in mortality figures.

In the present study, oliguria/anuria, anemia, volume overload, pRIFLE category failure at presentation, and the need for initiation of dialysis were significantly associated with poor renal outcomes in children with AKI. Multiple factors have been described as predictors of outcomes in AKI, again reflecting the heterogeneity of patient populations. In critically ill patients with AKI undergoing HD, cardiovascular co-morbidities, metabolic acidosis, and acute respiratory distress syndrome led to poor outcomes [22]. The age below 2 years, shock, fluid overload, the need for mechanical ventilation, multi-organ failure, and late referral predicted poor outcomes in a study from Kuwait [23].

In regression analysis, the presence of anuria, volume overload, and primary renal disease were found to be risk factors for starting dialysis (HD or PD) in the current study.

A notable strength of this study lies in its generation of primary data from Bangladesh, a low-resource developing country where public health funding remains severely constrained. In such a setting, the allocation of financial resources to healthcare often falls short, leaving little room for investment in health research. Therefore, the findings of this study contribute valuable insights to the understanding of pediatric AKI in a context where healthcare infrastructure and research are limited.

Conclusion

Gastroenteritis, sepsis, and RPGN were the leading causes of pediatric AKI, with a high recovery rate at a tertiary care center. Poor renal outcomes were linked to oliguria/anuria, anemia, volume overload, pRIFLE failure, and dialysis requirements. Longitudinal and multicenter studies are needed to inform preventive strategies to reduce pediatric AKI-related morbidity and mortality. Key prevention strategies include improved hygiene, early diagnosis, cautious use of nephrotoxic medications, fluid management, public education, better healthcare access, infection control, and follow-up care.

The study design has some critical limitations. The data in this study were collected from a single pediatric nephrology center, which may not fully capture the diverse range of causes of pediatric AKI observed across the entire nation. Additionally, newborns were excluded from the study due to the marked differences in their vulnerability to and the causes of AKI compared to older infants and children. Furthermore, children who had undergone cardiac surgery were not included, as there was insufficient data available for this subgroup.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

Conceptualization and visualization: Tahmina Jesmin; methodology and writing: Tahmina Jesmin and Nadira Sultana; Data curation, Software, and formal analysis: Nadira Sultana; Validation: Tahmina Jesmin, Abdullah Al Mamun, and Syed Saimul Huque; Investigation: Tahmina Jesmin, Abdullah Al Mamun, Mst Shanjida Sharmim; Supervision and resources: Tahmina Jesmin, Syed Saimul Huque, and Afroza Begum.

Conflict of interest

The authors declared no conflict of interest.

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