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Spectrum of Clinical Diseases Requiring Acute Hemodialysis and Its Outcomes Among Children in Pediatric Intensive Care Unit in a Tertiary Care Center

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ABSTRACT

Background: Acute kidney injury (AKI) is an important complication among critically ill children and may necessitate acute hemodialysis when severe renal dysfunction or associated metabolic complications develop. However, the spectrum of clinical conditions requiring hemodialysis and factors associated with outcomes in critically ill children remain insufficiently characterized. This study evaluated the clinical indications, outcomes, and factors associated with mortality among children requiring acute hemodialysis in a pediatric intensive care unit (PICU).

Methods: This prospective observational study included children aged 1 month to 12 years who underwent acute hemodialysis in the PICU of a tertiary care center. Demographic characteristics, underlying clinical conditions, indications for dialysis, duration of dialysis, urea clearance, complications, and clinical outcomes were recorded. Continuous variables were summarized using descriptive statistics, while categorical variables were expressed as frequencies and percentages. Binary logistic regression was used to assess factors associated with mortality, and the association between urea clearance categories and outcome was evaluated using the chi-square test. A p value <0.05 was considered statistically significant.

Results: Fifty-four children requiring acute hemodialysis were included. AKI was the most frequent indication for dialysis (34/54, 63.0%), followed by uremic manifestations (13/54, 24.1%), metabolic acidosis (8/54, 14.8%), and hyperkalemia (8/54, 14.8%). Overall, 24 children (44.4%) died, while 30 (55.6%) survived. Mortality was particularly high among children with hyperammonemia and metabolic acidosis. Metabolic acidosis was associated with increased odds of mortality, although the association did not reach statistical significance (OR, 7.88; 95% CI, 0.87–71.13; p=0.066). Urea clearance category was significantly associated with outcome (p=0.0099), with higher mortality observed in children with lower urea clearance.

Conclusion: Acute hemodialysis was required for a broad spectrum of clinical conditions in critically ill children, with AKI being the predominant indication. Mortality remained substantial, particularly among children with severe metabolic complications. Urea clearance

was significantly associated with outcome and may provide useful prognostic information in children undergoing acute hemodialysis.

Keywords: Acute hemodialysis, Acute kidney injury, Pediatric intensive care unit, Hemodialysis outcomes, Pediatric renal replacement therapy, Mortality, Urea clearance, Dialysis indications

INTRODUCTION

Acute kidney injury (AKI) is a common and serious clinical condition encountered in critically ill pediatric patients, especially those admitted to the Pediatric Intensive Care Unit (PICU) [1,2]. When medical management fails to stabilize the biochemical and fluid derangements in children with AKI, renal replacement therapy (RRT) becomes an essential component of supportive care [3].

Among various RRT modalities, acute hemodialysis (HD) plays a critical role in managing life-threatening complications of AKI, such as severe hyperkalemia, refractory metabolic acidosis, fluid overload, and uremic symptoms. In pediatric practice, initiating acute hemodialysis is often challenging due to technical limitations, the need for vascular access, hemodynamic instability, and individualized patient considerations based on age, weight, and underlying disease [4].

The spectrum of diseases that necessitate acute hemodialysis in children is broad and includes conditions such as sepsis, hemolytic uremic syndrome (HUS), acute glomerulonephritis, tumor lysis syndrome, nephrotoxic drug ingestion, and multi-organ dysfunction syndrome (MODS) [5].

Despite significant advances in pediatric nephrology and intensive care, the outcomes of children requiring acute hemodialysis remain variable. Mortality rates in children undergoing acute hemodialysis in PICU settings can range from 20% to over 50% in the presence of multi-organ failure or septic shock. Moreover, survivors of AKI are at risk of long-term sequelae, including chronic kidney disease (CKD), hypertension, and impaired growth and development [6].

Given the growing burden of pediatric AKI and the critical role of hemodialysis in its management, understanding the spectrum of clinical conditions leading to dialysis and evaluating outcomes is essential. This knowledge can inform timely decision-making, resource allocation, and the development of evidence-based protocols aimed at improving survival and reducing long-term complications. It also highlights the need for early recognition, risk stratification, and targeted interventions tailored to the specific needs of critically ill children.

MATERIALS & METHODS

Study design and setting

This prospective cohort study was conducted in the Pediatric Intensive Care Unit, Institute of Child Health and Hospital for Children, Egmore, Chennai, India, over an 18-month period (September 2023–February 2025).

Ethical considerations

The study protocol was reviewed and approved by the Institutional Ethics Committee before the commencement of the research (IEC Approval Number: MMC/Approval/51112023). Written informed consent was obtained from all patients before enrolment, and the confidentiality of patient information was maintained throughout the study.

Study population and sample size

The study population included children aged 1 month to 12 years who were admitted to the PICU and required acute hemodialysis during the study period. A total of 54 children were included in the study.

Inclusion and exclusion criteria

Children with acute clinical illnesses necessitating hemodialysis in a critical care setting were included. Children with known chronic kidney disease (CKD) presenting with acute deterioration requiring hemodialysis were also included. Children with CKD on regular maintenance hemodialysis were excluded from the study.

Data collection

Data were collected prospectively using a structured data collection proforma. Demographic and clinical details, indications for acute hemodialysis, dialysis parameters, laboratory values, complications, and patient outcomes were recorded. Pre- and post-dialysis biochemical parameters, urine output, ultrafiltration, duration of dialysis, and survival or mortality were documented.

Data Management

All collected data were entered into Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA; Microsoft Excel 2016) for organization and storage. Data were checked for completeness and accuracy before analysis. The confidentiality of patient details was maintained throughout the study.

Statistical Analysis

The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized using mean and standard deviation, while categorical variables were presented as frequencies and percentages. The association between clinical variables and mortality was assessed using binary logistic regression analysis, with odds ratios (ORs) and corresponding 95% confidence intervals (CIs) reported. The association between urea clearance categories and outcome was evaluated using the chi-square test. A two-sided p value <0.05 was considered statistically significant.

RESULT

A total of 54 pediatric patients admitted to the Pediatric Intensive Care Unit (PICU) who required acute hemodialysis were included in the study. Of these, the majority belonged to the 1–4 years age group, accounting for 38.8% of cases (n = 21). This was followed by the 5–8 years group with 31.4% (n = 17), and the 9–12 years group comprising 25.9% (n = 14). The extremes of age - <1 year and >12 years - were the least represented, each contributing 1.8% (n = 1) to the total. Notably, 96.1% of the children were between 1 and 12 years of age, indicating a predominance of hemodialysis requirement in this age bracket. Among the 54 children who underwent hemodialysis in the PICU, 31 were males, constituting 57.4% of the study population, while 23 were females, accounting for 42.5%. This indicates a male predominance in the cohort requiring hemodialysis [Figure 1].

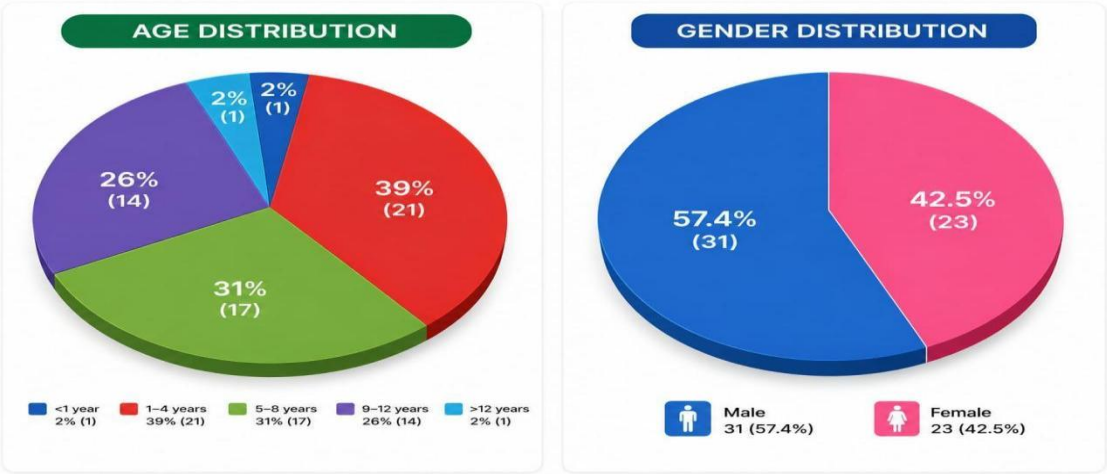

Figure 1: Baseline Characteristics of Study Participants (n=54)

Survival and mortality rates varied markedly depending on the underlying indication for dialysis, reflecting the diverse severity and reversibility of these conditions. AKI was the most common indication, accounting for 34 cases, with a survival rate of 52.94%, highlighting its serious prognosis in critically ill children. Severe hyperkalemia had an even higher survival rate of 87.5%, indicating that when promptly recognized and treated, outcomes can be significantly improved. Hepatic encephalopathy had a 50% survival rate, suggesting a guarded prognosis, possibly compounded by underlying liver failure. Meanwhile, hypertensive emergencies, though serious, had no recorded deaths in this cohort (recorded in 2 cases), suggesting potential reversibility with timely management. Lastly, uremic manifestations, seen in 13 children, had a survival rate of 61.54%. This included a spectrum of manifestations ranging from uremic encephalopathy, seizures, uremic pericarditis, and hypertension. Metabolic acidosis demonstrated one of the highest mortality burdens at 87.5%, affecting 8 children and resulting in 7 deaths, underscoring the severity of systemic derangements often associated with multiorgan dysfunction. Drug intoxications recorded a 100% mortality rate; although the small number of cases (1–3) limits generalizability, it still flags these as critical conditions with poor outcomes even when dialysis is initiated. Hyperammonemia, though rare, was also associated with a high mortality of 75%, reflecting its typically rapid progression and potential for irreversible neurologic injury. Overall, these data emphasize the need for indication-specific risk stratification and timely intervention, as outcomes differ significantly depending on the underlying cause necessitating dialysis [Table 1].

Table 1. Clinical Indications and Outcomes of Acute Hemodialysis

Indication	Total Cases	Deaths	Survival Rate (%)	Proportional Mortality Rate (%)
Acute kidney injury	34	16	52.94%	47.06%
Drug intoxications	3	3	0%	100.00%
Hepatic encephalopathy	2	1	50%	50.00%
Hyperammonemia	4	3	25%	75.00%
Metabolic acidosis (pH < 7.1)	8	7	12.5%	87.50%
Severe hyperkalemia	8	1	87.5%	12.50%
Uremic manifestations	13	5	61.54%	38.46%

Logistic regression analysis, using acute kidney injury (AKI) as the reference group, revealed important trends in mortality risk across dialysis indications. Metabolic acidosis had the highest odds of death (OR: 7.88), suggesting a strong association with fatal outcomes, although the wide confidence interval (0.87–71.13) and borderline significance (p = 0.066) reflect limited statistical power. Hyperammonemia also showed elevated odds (OR: 3.38), while fluid overload (OR: 0.40) and severe hyperkalemia (OR: 0.16) were associated with lower odds of death, suggesting relatively better prognoses when managed appropriately. While not all findings reached statistical significance, the observed trends align with the univariate analyses, reinforcing metabolic acidosis, hyperammonemia, and drug intoxication as high-risk indications for mortality in pediatric dialysis patients [Table 2].

Table 2. Association Between Clinical Indications and Mortality Outcomes

Indication	Odds Ratio (OR)	95% CI	p-value
Metabolic Acidosis	7.88	0.87–71.13	0.066
Hyperammonemia	3.38	0.32–35.79	0.313
Severe Hyperkalemia	0.16	0.02–1.45	0.104
Uremic Manifestations	0.70	0.19–2.59	0.597

Based on urea clearance levels, a total of 11 patients had clearance <30%, with 9 deaths, resulting in the highest mortality rate of 81.8% in this group. The 30–50% clearance group included 31 patients, among whom 9 died, yielding a mortality rate of 29.0%. In the 50–70% group, there were 7 patients, with 3 deaths, corresponding to a mortality rate of 42.9%. No patients were recorded in the 70–100% clearance group. Overall, urea clearance greater than 30% was associated with higher odds of survival. The association between urea clearance levels and mortality was found to be statistically significant (Chi-square test, p = 0.0099) [Table 3].

Table 3. Association Between Urea Clearance and Mortality Outcomes

Urea Clearance Group	Deaths	Survived	Total	Mortality Rate (%)
<30%	9	2	11	81.8%
30–50%	9	22	31	29.0%
50–70%	3	4	7	42.9%
70–100%	0	0	0	—
Chi-square test	p = 0.0099			

Longer dialysis durations were associated with a trend toward lower mortality; however, the difference did not reach statistical significance. Complications related to the hemodialysis process were observed at different stages. Prior to dialysis, one child developed bleeding at the catheter insertion site. After dialysis, eight children developed hypotension. Importantly, no complications directly attributable to the dialysis procedure itself were identified in any of the patients. The overall incidence of complications in this cohort of patients was 16.5%. These findings underscore the role of individual patient factors and the severity of underlying conditions in influencing adverse outcomes in critically ill pediatric populations.

In conclusion, this study demonstrated significant associations between urea clearance and mortality, with lower urea clearance associated with increased mortality. Outcomes also varied according to the indication for dialysis, with metabolic acidosis, hyperammonemia, and drug intoxications showing poorer outcomes. Overall mortality was 44.4%.

DISCUSSION

Among the clinical indications, acute kidney injury and hyperkalemia demonstrated the highest survival rates, with mortality rates of only 47% and 12.5%, respectively, particularly when treated early. The most frequent indication (63%) was acute kidney injury (AKI), which showed a survival rate of approximately 53%, though mortality remained substantial at 47%. Basu et al. reaffirmed AKI as a common cause of dialysis with adverse outcomes, particularly in the presence of sepsis or multi-organ dysfunction [7].

Conversely, metabolic acidosis was the most fatal indication, with only 12.5% survival and mortality as high as 87.5%. Logistic regression identified it as the strongest independent predictor of death (OR: 12.75). Drug intoxications, though uncommon (n = 3), had no survivors, with 100% mortality, consistent with previous literature describing irreversible multi-organ failure or delayed presentation as contributors to poor outcomes [8]. Hyperammonemia was also associated with poor survival (25%), often due to delayed diagnosis or underlying metabolic disease [9].

Urea clearance also became a prognostic indicator. Patients with clearance <30% had 81.8% mortality and those with 30–50% clearance had the maximum survival (74.2%). Surprisingly, the study found a non-linear pattern: increased clearance greater than 50% did not result in improved outcomes. This may be indicative of hidden patient frailty or the effect of non-dialytic variables. Hyperclearance has been noted to

lead to hemodynamic instability and osmotic shifts in small children (Ronco et al. **[10]**).

In this cohort, no complications were directly linked to the dialysis procedure itself. However, hypotension was the most common adverse event, observed in eight patients following dialysis. Although seizures and other intradialytic complications were not reported, the presence of hypotension remains clinically significant due to its known association with poor outcomes in critically ill children. These findings reinforce the importance of vigilant hemodynamic monitoring before, during, and after dialysis, as emphasized by the Pediatric Nephrology Committee (PNC, 2018). The relationship between hemodynamic instability and increased mortality has similarly been highlighted in studies by Arikan et al. and Selewski et al. **[11,12]**.

This study has certain limitations. Being a single-center study, the findings may have limited generalizability to other settings. Additionally, the observational study design limits the ability to establish causal relationships between the identified factors and patient outcomes.

Future studies should include larger, multicenter cohorts across different regions to improve the generalizability of the findings. Standardized definitions and protocols for acute kidney injury and renal replacement therapy should be adopted to facilitate comparisons between studies. Further research should focus on long-term renal and developmental outcomes, as well as the role of early versus delayed initiation of hemodialysis and optimization of dialysis prescriptions to improve outcomes in critically ill children.

CONCLUSION

In conclusion, this investigation reiterates the multifactorial basis of pediatric hemodialysis mortality. No single parameter in itself predicts outcome; instead, it is the interplay between the severity of the indication, intrinsic nutritional and metabolic status, effectiveness of dialysis, and procedural safety. The evidence supports combining multidomain measurements—clinical, biochemical, and anthropometric—to facilitate early risk stratification and individualized care. This study also emphasizes the importance of dialysis-related parameters, such as urea clearance, and the predictive value of certain indications for survival. It sets the stage for protocol-based, outcome-focused practice in pediatric dialysis, particularly in low-resource settings.

Declaration

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