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TO EVALUATE SERUM BICARBONATE, SODIUM AND CALCULATED SERUM OSMOLALITY AS MARKERS OF PREDICTING EARLY AKI (<3 DAYS OF ADMISSION) AND THEIR CORRELATION WITH PRIFLE CRITERIA AND KDIGO CRITERIA OF ACUTE KIDNEY INJURY STAGING AT A TERTIARY CARE CENTRE

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ABSTRACT

Background: Acute Kidney Injury (AKI) is a critical condition in pediatric intensive care units with significant morbidity and mortality. Early biomarkers for AKI prediction remain limited. This study aimed to evaluate serum bicarbonate, sodium and calculated serum osmolality as markers for predicting early AKI within three days of admission and analyze their correlation with pRIFLE and KDIGO criteria.

Materials and Methods: This hospital-based observational study was conducted at Mahatma Gandhi Medical College & Hospital, Jaipur from April 2023 to August 2024. Ninety pediatric patients aged 1-15 years admitted to PICU through emergency room were included. Patients with pre-existing kidney disease were excluded. Serum bicarbonate, calculated serum osmolality, and eGFR were measured at 0, 24, and 48 hours. AKI staging was performed using both pRIFLE and KDIGO criteria.

Results: The study included 90 patients with mean age 4.93±3.92 years, predominantly males (68.9%). Mean AKI duration was 5.30±3.49 days with 67.8% recovering within 1-5 days. Serum bicarbonate showed significant correlation with AKI progression, declining from 22.09±3.42 mmol/L at baseline to 17.18±3.11 mmol/L in pRIFLE Failure group at 48 hours ($p=0.001$). Serum osmolality increased significantly with AKI severity, reaching 402.70±23.62 mOsm/kg in Failure group. Strong positive correlations were observed between bicarbonate and eGFR ($r=0.279$-0.303, $p<0.05$) and between osmolality and eGFR ($r=0.706$-0.750, $p<0.001$). pRIFLE identified 85.1% patients as Risk category while KDIGO showed more distributed staging (47.8% Stage I, 34.4% Stage II, 17.8% Stage III).

Conclusion: Serum bicarbonate and calculated serum osmolality serve as valuable early biomarkers for AKI prediction and staging. Bicarbonate levels correlate inversely with AKI severity while osmolality increases with disease progression. Both biomarkers complement traditional criteria in early AKI detection and risk stratification.

Keywords: Acute kidney injury, bicarbonate, serum osmolality, pRIFLE, KDIGO, pediatric intensive care.

INTRODUCTION

Acute Kidney Injury (AKI) is a critical condition commonly encountered in Pediatric Intensive Care Units (PICUs), significantly contributing to increased morbidity and mortality among hospitalized children.[1] The reported incidence of AKI in PICUs ranges from 10% to 35% with an even higher prevalence in mechanically ventilated children and those on inotropic support.[2] AKI is defined by an abrupt decline in renal function within 48 hours, typically determined by reduced urine output and a drop in the estimated glomerular filtration rate (eGFR). Early recognition and management of AKI are essential to prevent long-term complications such as chronic kidney disease (CKD), fluid overload, electrolyte imbalances and multi-organ dysfunction. Over the years, several standardized criteria have been developed for diagnosing and staging AKI. The pRIFLE criteria (Pediatric Risk, Injury, Failure, Loss and End-stage renal disease) were introduced in 2007 as the first pediatric-specific AKI classification system.[3] This framework stratifies AKI into different severity levels based on changes in urine output and eGFR. However, the KDIGO (Kidney Disease Improving Global Outcomes) classification, established in 2012 has become the most widely used standard for both pediatric and adult AKI assessment.[4] The KDIGO criteria offer a comprehensive and universal definition that helps in early detection, risk stratification and treatment planning for pediatric AKI.

Metabolic acidosis is a well-documented phenomenon in pediatric AKI and has been strongly correlated with cardiac dysfunction, hypotension, increased risk of sepsis and higher mortality rates. The accumulation of acidic metabolic byproducts due to impaired renal excretion results in a drop in serum bicarbonate levels, further exacerbating systemic inflammation and organ dysfunction.[5] Measuring serum bicarbonate levels at admission and within 48 hours of ICU stay has been suggested as a significant early biomarker for predicting AKI severity and progression. Low bicarbonate levels are often associated with worsening renal function, systemic inflammation and hemodynamic instability, making them a valuable parameter in risk stratification for AKI patients. Serum osmolality is another crucial marker in assessing kidney function and predicting patient outcomes in critically ill children. It reflects the concentration of dissolved ions and particles in the blood and is strongly influenced by sodium, potassium, glucose and urea levels.[6] Abnormal serum osmolality, whether elevated or reduced, has been linked to worse clinical outcomes in critically ill patients. Studies have shown that both high and low serum osmolality are associated with increased mortality, forming a U-shaped relationship where deviations from the normal range lead to adverse effects on cellular function, vascular integrity and immune responses.[7] Elevated serum osmolality has also been identified as an independent risk factor for chronic kidney disease progression, further emphasizing its importance in critically ill pediatric patients.[8,9] The current study aims to analyze the dynamic changes in these biochemical markers as potential early indicators of pediatric AKI and evaluate their correlation with pRIFLE staging. Understanding these relationships could help refine risk prediction models, facilitate timely therapeutic interventions and ultimately improve clinical outcomes for critically ill children at risk of AKI.

MATERIALS AND METHODS

Study Design and Setting: This hospital-based observational study was conducted at the Pediatric Emergency Room (ER) and Pediatric Intensive Care Unit (PICU) of Mahatma Gandhi Medical College & Hospital, Jaipur. The study period extended from April 1, 2023 to August 31, 2024. Ethical approval was obtained from the Institute Ethics Committee before initiating the study to ensure strict adherence to research guidelines, patient safety and ethical considerations. Written informed consent was collected from all participants before their enrollment, ensuring that they fully understood the study's objectives, methodology and potential risks.

Study Population and Selection Criteria: The study included all patients diagnosed with or at risk of acute kidney injury (AKI) within the first three days of admission, meeting the inclusion and exclusion criteria. Inclusion criteria comprised pediatric patients aged 1 to 15 years admitted to the PICU through the Emergency Room. Exclusion criteria included patients less than 1 month of age and greater than 15 years of age, patients already diagnosed with kidney disease at the time of admission, patients who already had established acute kidney injury at the time of admission, parents who refused to give consent for the study, and patients who were admitted for more than two days in other hospitals before being referred to Mahatma Gandhi Hospital for further management.

Data Collection and Laboratory Investigations: Upon selection, each patient underwent catheterization for accurate urine output measurement and baseline weight was recorded for further calculations. To establish baseline renal function and metabolic status, venous blood samples were collected for analysis of blood gas parameters, serum electrolytes, blood urea, serum creatinine and blood sugar levels. At 0 hours (upon admission to the PICU), an initial blood sample was taken to measure serum bicarbonate levels, calculated serum osmolality and estimated glomerular filtration rate (eGFR). The assessment at this stage helped in identifying any pre-existing renal dysfunction. Acute Kidney Injury staging was determined at this time point using the pRIFLE criteria based on eGFR, which is a widely accepted classification system for AKI severity.

At 24 hours, a second set of blood samples was collected for serum bicarbonate, calculated serum osmolality and eGFR and urine output was also measured. The combination of eGFR and urine output provided a more comprehensive AKI evaluation, as urine output is a critical parameter in assessing renal function. AKI staging was performed again using the pRIFLE criteria, incorporating both eGFR and urine output measurements to enhance diagnostic accuracy. At 48 hours, a final blood sample was taken to reassess serum bicarbonate, calculated serum osmolality and eGFR, along with urine output measurement. AKI staging was conducted at this point based on the pRIFLE criteria, allowing a time-based assessment of renal function deterioration or improvement.

All investigations were performed in a National Accreditation Board for Testing and Calibration Laboratories (NABL) certified laboratory at Mahatma Gandhi Medical College & Hospital, Jaipur, ensuring high accuracy, reliability and standardization of laboratory parameters. The collected data enabled a comparative analysis of pRIFLE and KDIGO criteria for AKI staging, providing insights into the correlation between these classification systems and the role of metabolic parameters in early AKI detection.

Statistical Analysis: The data were analyzed using SPSS 23.0 version. The results were presented in the form of frequency distributions, means, standard deviations and graphical representations. For the comparison of qualitative variables, the chi-square test was applied whenever necessary to determine statistical significance. Quantitative variables were analyzed using the t-test to assess differences between groups. A p-value of less than 0.05 was considered statistically significant, ensuring the reliability of the findings.

RESULTS

The 90 pediatric patients included in this study. The cohort demonstrated a diverse age distribution with a mean age of 4.937±3.926 years. The largest proportion of patients (38.9%) fell within the 1-5 years age group, followed by 6-10 years (26.7%), less than 1 year (21.1%), and 11-15 years (13.3%). A notable male predominance was observed with 62 patients (68.9%) being male and 28 patients (31.1%) being female. The mean height was 98.88±23.63 cm and mean weight was 16.05±11.11 kg, reflecting the pediatric nature of the cohort with significant variability due to the broad age range. The mean duration of AKI was 5.30±3.498 days, with the majority of patients (67.8%) experiencing AKI for 1-5 days, indicating relatively short-term episodes in most cases.

Table 1: Patient Demographics and Clinical Characteristics

Parameter	n (%)
Age Distribution	
Mean age (years)	4.937 ± 3.926
<1 year	19 (21.1%)
1-5 years	35 (38.9%)
6-10 years	24 (26.7%)
11-15 years	12 (13.3%)
Gender Distribution	
Male	62 (68.9%)
Female	28 (31.1%)
Anthropometric Measurements	
Mean Height (cm)	98.88 ± 23.63
Mean Weight (kg)	16.05 ± 11.11
AKI Duration	
Mean duration (days)	5.30 ± 3.498
1-5 days	61 (67.8%)
6-10 days	24 (26.7%)
11-15 days	4 (4.4%)
>15 days	1 (1.1%)

Urine Output and Serum Electrolyte Parameters: The comparison of urine output between pRIFLE and KDIGO criteria revealed significant differences at specific time points. At baseline, both criteria showed similar mean urine outputs (pRIFLE: 338.00 ml, KDIGO: 351.33 ml) with no significant statistical differences. However, at 24 hours, a statistically significant difference emerged with pRIFLE patients showing higher urine output (451.83 ml) compared to KDIGO patients (326.58 ml, p=0.040). This pattern suggests that pRIFLE criteria may classify patients as having better renal function during early AKI stages compared to KDIGO. By 48 hours, both criteria showed declining urine output, though pRIFLE continued to demonstrate higher values. Serum electrolyte analysis revealed interesting patterns across the study period. Sodium levels remained remarkably stable across both classification systems at all time points, with mean values around 137-138 mEq/L and no significant differences (p>0.05). Similarly, chloride levels showed consistent stability with mean values around 106-108 mEq/L across all measurements. However, potassium demonstrated more dynamic behavior, particularly at 24 hours where pRIFLE showed a statistically significant variation (p=0.016), with lower mean potassium

levels compared to baseline values. This finding suggests that potassium metabolism may be more sensitively reflected in the pRIFLE classification system during the acute phase of kidney injury.

Kidney Function Parameters: Blood urea and serum creatinine levels demonstrated highly significant changes across AKI stages and time intervals. At baseline, both parameters showed modest elevations, but by 48 hours, dramatic increases were observed. Blood urea levels rose significantly in both criteria ($p<0.001$), with pRIFLE Failure group reaching 88.62±31.90 mg/dL and KDIGO Stage III achieving 82.65±34.31 mg/dL. Serum creatinine followed an even more pronounced pattern, with pRIFLE Failure group reaching 3.08±1.13 mg/dL and KDIGO Stage III achieving 3.81±0.65 mg/dL at 48 hours ($p<0.001$). These elevations clearly demonstrate the progressive nature of renal dysfunction and validate both classification systems' ability to capture disease severity. Interestingly, blood glucose levels remained relatively stable across AKI stages and time points, with no statistically significant variations observed. Mean values fluctuated modestly around 100-125 mg/dL, suggesting that hyperglycemia was not a prominent feature in this AKI cohort and that glucose metabolism was not significantly impacted by the degree of kidney dysfunction observed.

Arterial Blood Gas Analysis: Arterial blood gas parameters provided crucial insights into acid-base status during AKI progression. pH values remained within normal physiological limits across both classification systems and all time points, ranging from 7.36 to 7.43 with no significant differences ($p>0.05$). This stability suggests that severe acidemia was not a predominant feature in this cohort, likely reflecting adequate compensatory mechanisms or timely supportive care. Similarly, pO_2 and pCO_2 levels showed no significant variations across AKI stages, indicating that respiratory function and gas exchange were not substantially compromised by kidney dysfunction alone. However, bicarbonate levels demonstrated the most clinically significant changes among all blood gas parameters. A clear downward trend was observed with increasing AKI severity. In the pRIFLE classification, bicarbonate declined from 22.09±3.42 mmol/L at baseline in the Risk group to 17.18±3.11 mmol/L in the Failure group at 48 hours ($p=0.001$). KDIGO staging showed similar patterns, with Stage III patients having significantly lower bicarbonate levels (16.68±2.41 mmol/L) compared to Stage I (21.61±3.98 mmol/L, $p=0.001$). This progressive decline in bicarbonate clearly indicates the development of metabolic acidosis as a key feature of advancing AKI and validates bicarbonate as a sensitive biomarker for disease progression.

Serum Osmolality and eGFR Changes

Table 2: Serum Osmolality and eGFR levels between pRIFLE and KDIGO criteria of the patients

Time intervals	pRIFLE Criteria				KDIGO Criteria			
	Score	Mean	SD	P value	Score	Mean	SD	P value
	SERUM OSMOLALITY							
Baseline	Risk	381.18	28.28	0.028*	Stage I	376.58	25.66	0.015*
	Injury	379.78	25.95		Stage II	386.56	27.26	
	Failure	395.02	31.36		Stage III	404.69	35.17	
	Total	383.16	28.31		Total	383.16	28.31	
24 hr	Risk	390.27	24.78	0.045*	Stage I	390.74	25.54	0.039*
	Injury	386.15	24.09		Stage II	385.98	22.50	
	Failure	389.41	18.91		Stage III	388.32	14.62	
	Total	388.70	23.43		Total	388.70	23.43	
48 hr	Risk	394.91	18.18	0.021*	Stage I	394.56	19.84	0.044*
	Injury	387.40	24.62		Stage II	391.14	23.05	
	Failure	402.70	23.62		Stage III	398.97	29.29	
	Total	393.71	21.98		Total	393.71	21.98	
	estimated Glomerular Filtration Rate (eGFR)							
Baseline	Risk	75.74	32.99	0.015*	Stage I	71.12	32.59	0.037*
	Injury	66.81	25.40		Stage II	69.20	26.19	
	Failure	54.97	20.46		Stage III	56.90	21.14	
	Total	68.97	29.34		Total	68.97	29.34	
24 hr	Risk	39.54	17.09	0.006*	Stage I	38.43	16.56	0.040*
	Injury	35.15	13.15		Stage II	33.96	14.61	
	Failure	25.08	11.60		Stage III	25.58	10.62	
	Total	35.46	15.69		Total	35.46	15.69	
48 hr	Risk	40.48	18.50	0.001*	Stage I	39.15	18.00	0.001*
	Injury	32.34	11.45		Stage II	30.42	13.25	
	Failure	15.07	7.91		Stage III	12.22	5.34	
	Total	33.16	17.36		Total	33.16	17.36	

* Significant ($P<0.05$)

Serum osmolality demonstrated statistically significant variations across AKI stages and time intervals, making it a valuable biomarker for disease monitoring. At baseline, osmolality increased progressively with AKI severity, ranging from 381.18±28.28 mOsm/kg in pRIFLE Risk group to 395.02±31.36 mOsm/kg in the Failure group ($p=0.028$). KDIGO staging showed similar trends

with Stage III reaching 404.69±35.17 mOsm/kg (p=0.015). By 48 hours, osmolality values remained elevated in severe AKI groups, with pRIFLE Failure maintaining 402.70±23.62 mOsm/kg and KDIGO Stage III at 398.97±29.29 mOsm/kg. These findings indicate that hyperosmolar states develop progressively with worsening kidney function, likely reflecting dehydration, fluid shifts, or solute retention. Estimated glomerular filtration rate (eGFR) provided the most direct measure of kidney function decline throughout the study period. At baseline, eGFR was moderately reduced across all groups, with pRIFLE Risk group averaging 75.74±32.99 mL/min/1.73m² and declining to 54.97±20.46 in the Failure group (p=0.015). By 48 hours, the decline became dramatically apparent, with eGFR dropping to critically low levels: 15.07±7.91 mL/min/1.73m² in pRIFLE Failure and 12.22±5.34 mL/min/1.73m² in KDIGO Stage III (p<0.001). These progressive reductions clearly demonstrate the evolution of kidney dysfunction and validate both classification systems' ability to capture functional deterioration over time.

Table 3: Comparison between pRIFLE and KDIGO criteria of the patients

		KDIGO Stage			Total	χ2 and P value
		Stage 1	Stage 2	Stage 3		
pRIFLE criteria	Risk	40	3	0	43	χ2 = 92.748 P=0.001*
		85.1%	8.8%	0.0%	47.8%	
	Injury	7	24	0	31	
		14.9%	70.6%	0.0%	34.4%	
	Failure	0	7	9	16	
		0.0%	20.6%	100.0%	17.8%	
Total		47	34	9	90	
		100.0%	100.0%	100.0%	100.0%	

* Significant (P<0.05)

The distribution of patients across different stages reveals significant differences between the two criteria. According to the pRIFLE criteria, the majority of patients are classified as being in the "Risk" stage (85.1%) with only a small proportion in the "Injury" category (14.9%), and no patients are classified under the "Failure" stage. In contrast, the KDIGO criteria show a more even distribution, with 47.8% of patients classified in "Stage I", 34.4% in "Stage II", and 17.8% in "Stage III". This difference is statistically significant (P = 0.001), indicating that pRIFLE tends to categorize a larger proportion of patients in the less severe "Risk" stage, while KDIGO assigns more patients to the higher stages of AKI. This variance suggests that pRIFLE may be less stringent in classifying the severity of AKI compared to KDIGO. Consequently, this difference in classification may have clinical implications, as the treatment approach could be influenced by how patients are categorized in terms of severity under each system.

Clinical Outcomes and Interventions

Renal replacement therapy (RRT) was required in 6 patients (6.7%) across both classification systems, though the distribution differed between staging categories. Under pRIFLE criteria, 4 patients in the Risk category and 2 in the Failure category required RRT, while KDIGO distributed these cases across all three stages (4 in Stage I, 1 in Stage II, 1 in Stage III). Despite these distributional differences, no statistically significant association was found between classification system and RRT requirement (p>0.05). Hospital length of stay showed no significant differences between classification systems, with overall mean duration of 18.79±15.65 days. Both pRIFLE and KDIGO demonstrated trends toward longer stays in higher severity categories, though statistical significance was not achieved. This finding suggests that both classification systems are equally effective in identifying patients who will require prolonged hospitalization and intensive management.

Table 4: Outcome between pRIFLE and KDIGO criteria of the patients

		Outcome		Total	χ2 and P value
		Death	Discharge		
pRIFLE criteria	Risk	3	40	43	χ2 = 23.260 P=0.014*
		30.0%	50.0%	47.8%	
	Injury	6	25	31	
		60.0%	31.3%	34.4%	
	Failure	1	15	16	
		10.0%	18.8%	17.8%	
Total		10	80	90	
		100.0%	100.0%	100.0%	
KDIGO criteria	Stage I	5	42	47	χ2 = 37.067 P=0.008*
		50.0%	52.5%	52.2%	
	Stage II	4	30	34	
		40.0%	37.5%	37.8%	
	Stage III	1	8	9	
		10.0%	10.0%	10.0%	

Total	10	80	90	
	100.0%	100.0%	100.0%	

* Significant (P<0.05)

There is a significant difference in the outcomes between the two classification systems. Under the pRIFLE criteria, a higher proportion of patients in the "Injury" stage (60%) required RRT and subsequently died, compared to those in the "Risk" (30%) and "Failure" (10%) stages. In total, 10 patients required RRT, with 3 dying and 7 being discharged. Under the KDIGO criteria, the distribution of patients requiring RRT and their outcomes are also observed, with 50% of patients in "Stage I" requiring RRT and 60% of patients in "Stage II" needing the intervention, while only 10% of "Stage III" patients required RRT. The P-values for both pRIFLE and KDIGO are statistically significant (P = 0.014 for pRIFLE and P = 0.008 for KDIGO), indicating that the outcomes—whether patients required RRT or not differed significantly depending on the classification system. This suggests that although both systems identify the need for RRT, there are differences in how each system predicts patient outcomes in terms of survival or discharge.

Correlation Analysis

Spearman's correlation analysis revealed important relationships between biomarkers and traditional measures of kidney function. Bicarbonate levels showed significant positive correlations with eGFR at all time points (baseline: r=0.279, p=0.008; 24 hours: r=0.303, p=0.004; 48 hours: r=0.265, p=0.012), indicating that as kidney function declines, bicarbonate levels consistently decrease. Similarly, serum osmolality demonstrated strong positive correlations with serum creatinine at 24 and 48 hours (r=0.671 and r=0.681 respectively, p<0.001), suggesting that osmolality increases proportionally with worsening kidney function. The correlation between bicarbonate and serum creatinine was particularly noteworthy, showing no significant relationship at baseline (r=-0.141, p>0.05) but developing strong positive correlations at 24 hours (r=0.671, p<0.001) and 48 hours (r=0.681, p<0.001). This pattern indicates that bicarbonate becomes an increasingly reliable marker of kidney dysfunction as AKI progresses, making it valuable for monitoring disease evolution rather than initial diagnosis.

DISCUSSION

Our study provides comprehensive evidence for the utility of serum bicarbonate and calculated serum osmolality as early biomarkers for pediatric AKI prediction and staging. The findings demonstrate that these biochemical parameters offer valuable adjunctive information to traditional AKI classification systems and may enhance early detection and risk stratification capabilities. The demographic profile of our cohort aligns well with existing pediatric AKI literature. The mean age of 4.93±3.92 years and predominance of patients in the 1-5 year age group (38.9%) is consistent with findings from Soomro et al. (2018)10, who reported a mean age of approximately 3.6 years with nearly half of their cohort falling within the 12-60 month range. Similarly, Srinivasa et al,[11] (2016) observed a mean age of around 4.3 years, indicating that early childhood represents a particularly vulnerable period for AKI development in pediatric intensive care settings. The notable male predominance (68.9%) in our study exceeds the moderate male predominance reported by Srinivasa et al,[11] (2016) and the near-equal gender distribution observed by Soomro et al. (2018)10, suggesting potential regional or institutional factors influencing AKI susceptibility patterns. The mean AKI duration of 5.30±3.49 days with 67.8% of patients recovering within 1-5 days reflects the generally favorable prognosis of pediatric AKI when detected early and managed appropriately. This duration is consistent with reports from Soomro et al,[10] (2018) and Srinivasa et al,[11] (2016) who observed typical resolution within 5-7 days in PICU settings. The relatively short duration in most cases suggests effective early intervention protocols and highlights the importance of prompt recognition and treatment initiation.

The progressive decline in serum bicarbonate levels across AKI stages represents one of our most significant findings. The decrease from 22.09±3.42 mmol/L at baseline to 17.18±3.11 mmol/L in the pRIFLE Failure group demonstrates the development of metabolic acidosis as kidney function deteriorates. This finding aligns with Sun et al,[12] (2024) who reported significantly lower pH and bicarbonate values in sepsis-associated AKI patients. The strong positive correlations between bicarbonate and eGFR (r=0.265-0.303, p<0.05) throughout the study period validate bicarbonate as a reliable marker of kidney function decline and suggest its potential utility in early AKI detection protocols. Serum osmolality demonstrated equally compelling patterns, with progressive increases from 381.18±28.28 mOsm/kg in early AKI to over 400 mOsm/kg in advanced stages. This hyperosmolar state likely reflects fluid shifts, solute retention, and impaired renal concentration ability characteristic of progressing kidney dysfunction. The strong correlations with both serum creatinine (r=0.671-0.681, p<0.001) and eGFR (r=0.706-0.750, p<0.001) at 24 and 48 hours establish osmolality as a valuable complementary biomarker for AKI monitoring. These findings contrast with Likhitha et al,[13] (2023) who found no significant osmolality differences between AKI and non-AKI patients in diabetic ketoacidosis, suggesting that the utility of osmolality may vary depending on the underlying pathophysiology.

The comparison between pRIFLE and KDIGO classification systems revealed important differences in staging sensitivity and distribution. Our

observation that pRIFLE classified 85.1% of patients as "Risk" while KDIGO showed more distributed staging (47.8% Stage I, 34.4% Stage II, 17.8% Stage III) aligns with findings from multiple comparative studies. Sun et al,[12] (2024) reported similar patterns with pRIFLE identifying more AKI cases overall (74.2% vs 67.7% for KDIGO), while maintaining good agreement ($\kappa > 0.60$) between the systems. This suggests that pRIFLE may be more sensitive for early-stage detection but potentially less specific for advanced stages, while KDIGO provides more graduated severity assessment. The kidney function parameters in our study demonstrated expected patterns of progressive deterioration. The dramatic increases in serum creatinine (reaching 3.08±1.13 mg/dL in pRIFLE Failure and 3.81±0.65 mg/dL in KDIGO Stage III) and blood urea levels validate both classification systems' ability to capture severe kidney dysfunction. These values align closely with reports from Chowdhary et al,[14] (2018) who found peak serum creatinine levels predictive of mortality in extremely low birth weight infants, and with Ueno et al,[15] (2019) who observed significant creatinine elevations in post-cardiac surgical infants with AKI.

The correlation analysis revealed particularly interesting temporal patterns. The lack of significant correlation between bicarbonate and serum creatinine at baseline ($r=-0.141$, $p>0.05$) but development of strong correlations at 24 and 48 hours ($r=0.671$-0.681, $p<0.001$) suggests that bicarbonate becomes increasingly valuable for monitoring AKI progression rather than initial diagnosis. This temporal evolution supports the concept that biochemical markers may have different utilities at various stages of AKI development and progression.

Clinical outcomes in our study, including the relatively low renal replacement therapy requirement (6.7%) and mean hospital stay of 18.79±15.65 days, reflect the generally favorable prognosis when AKI is detected early and managed appropriately. These outcomes are consistent with reports from Al Amri et al,[16] (2022) who observed similar dialysis requirements and hospital stays in their PICU cohort. The lack of significant differences in outcomes between pRIFLE and KDIGO classifications suggests that both systems are equally effective for predicting clinical course and resource utilization.

The stability of serum electrolytes, particularly sodium and chloride, across AKI stages suggests that these traditional markers may have limited utility for AKI staging in pediatric patients. The modest variations in potassium levels, while statistically significant at certain time points, were not as pronounced as the changes observed in bicarbonate and osmolality. This pattern reinforces the superior utility of acid-base and osmolar markers compared to routine electrolyte measurements for AKI monitoring. Our findings have important clinical implications for pediatric intensive care practice. The demonstration that serum bicarbonate and osmolality provide early and sensitive indicators of AKI progression suggests these parameters should be incorporated into routine monitoring protocols for at-risk children. The strong correlations with traditional markers like serum creatinine and eGFR validate their utility as complementary biomarkers that may enhance early detection capabilities before significant functional decline occurs. The study also highlights the complementary nature of pRIFLE and KDIGO criteria, with each system offering unique advantages in different clinical contexts. The higher sensitivity of pRIFLE for early-stage detection combined with KDIGO's more graduated severity assessment suggests that using both systems in parallel may provide optimal diagnostic and prognostic information for clinical decision-making.

CONCLUSION

This study demonstrates that serum bicarbonate and calculated serum osmolality serve as valuable early biomarkers for predicting and staging pediatric acute kidney injury. Both parameters show strong correlations with traditional markers of kidney function and provide complementary information to existing classification systems. Serum bicarbonate levels decline progressively with AKI severity, reflecting the development of metabolic acidosis as kidney function deteriorates. Conversely, serum osmolality increases with disease progression, indicating fluid and solute retention characteristic of advancing kidney dysfunction. The temporal evolution of these biomarkers, particularly their strengthening correlations with kidney function over 24-48 hours, suggests they are most valuable for monitoring AKI progression rather than initial diagnosis. Both pRIFLE and KDIGO criteria demonstrate utility in pediatric AKI staging, with pRIFLE showing higher sensitivity for early detection and KDIGO providing more distributed severity assessment. Integration of serum bicarbonate and osmolality measurements into routine pediatric intensive care monitoring protocols may enhance early AKI detection and improve risk stratification capabilities. These findings support the development of multiparameter diagnostic algorithms that combine traditional criteria with novel biochemical markers to optimize pediatric AKI management and outcomes. Future research should focus on validating these biomarkers in larger multicenter cohorts and investigating their utility in specific pediatric populations such as cardiac surgery patients, neonates, and children with sepsis. Additionally, studies examining the cost-effectiveness of incorporating these markers into routine care protocols would provide valuable information for healthcare policy development.

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