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Seasonal Patterns in Acute Kidney Injury: Incidence, Etiology and Severity in A Tertiary Care Setting

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ABSTRACT

Acute kidney injury (AKI) remains a significant contributor to morbidity and mortality among hospitalized patients, particularly in low- and middle-income countries where environmental and infectious factors play a crucial role (1–3). Seasonal variation in AKI has been increasingly recognized, yet evidence from tropical regions remains sparse (10,15). This prospective observational study evaluated 200 consecutive patients diagnosed with AKI based on Kidney Disease: Improving Global Outcomes (KDIGO) criteria (1) in a tertiary care center. Patients were categorized into four seasonal groups, and associations between season, etiology, and severity were analyzed. The incidence of AKI demonstrated a bimodal distribution, peaking during summer (35%) and monsoon (30%), followed by winter (25%) and spring (10%). A statistically significant association was observed between season and etiology ($p < 0.001$), with dehydration emerging as the predominant cause in summer and sepsis in monsoon. Although severe AKI (Stage 3) was more frequent during monsoon, the variation in severity across seasons did not reach statistical significance ($p = 0.17$). These findings highlight distinct seasonal patterns in AKI in tropical settings, driven primarily by environmental heat stress and infection burden, underscoring the need for season-specific preventive strategies and optimized healthcare resource allocation.

***Keywords**: Acute kidney injury (AKI), Seasonal variation, KDIGO criteria, Dehydration and sepsis, Tropical healthcare settings.*

INTRODUCTION

Acute kidney injury (AKI) is a complex and multifactorial clinical syndrome characterized by an abrupt decline in renal function, resulting in impaired regulation of fluid, electrolyte, and acid–base homeostasis, along with accumulation of metabolic waste products (1). It is increasingly recognized as a global public health concern due to its strong association with prolonged hospitalization, increased healthcare costs, and high short- and long-term mortality (2,3). The burden of AKI is particularly pronounced in low- and middle-income countries, where delayed presentation, limited healthcare infrastructure, and a higher prevalence of infectious diseases contribute to worse outcomes (2,4). Epidemiological studies have reported a wide variation in AKI incidence, ranging from 7% to over 50% among hospitalized patients, with even higher rates in critically ill populations (4–6). Importantly, AKI is not only an independent predictor of in-hospital mortality but also a significant risk factor for the development of chronic kidney disease and end-stage renal disease (3,5).

In recent years, there has been growing interest in understanding the role of environmental and seasonal factors in the epidemiology of AKI. Seasonal variation is well established in several disease processes, including infectious, cardiovascular, and respiratory conditions, where fluctuations in temperature, humidity, and environmental exposures influence disease patterns (10–14). These variations may indirectly affect kidney function through mechanisms such as dehydration, hemodynamic instability, systemic infections, and toxin exposure. For instance, extreme heat during summer months can lead to volume depletion and prerenal azotemia, while increased prevalence of infections during rainy seasons may predispose individuals to sepsis-associated intrinsic renal injury (10,14).

Most of the existing literature on seasonal variation in AKI originates from temperate regions, where a higher incidence during winter months has been attributed to increased cardiovascular events and infections (11–13,15). However, these findings may not be directly applicable to tropical regions, where climatic conditions, disease patterns, and healthcare challenges differ substantially. In tropical settings, high ambient temperatures, monsoon-related infections, and socioeconomic factors may create a unique epidemiological profile of AKI. Despite this, data from such regions remain limited, and there is a lack of comprehensive prospective studies examining seasonal trends in AKI incidence, etiology, and severity (15).

Understanding these seasonal patterns is crucial for developing targeted preventive strategies, improving early recognition, and optimizing healthcare resource allocation, particularly in resource-limited settings. Therefore, the present study was designed to evaluate the seasonal variation in incidence, etiological spectrum, and severity of AKI among patients admitted to a tertiary care hospital in a tropical region.

MATERIALS AND METHODS

This hospital-based observational study was conducted at a tertiary care center over a defined study period. A total of 200 consecutive adult patients diagnosed with acute kidney injury (AKI) were enrolled. AKI was defined and staged according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria (1), based on changes in serum creatinine and/or urine output. Patients aged 18 years and above who fulfilled the diagnostic criteria for AKI were included in the study. Patients with pre-existing chronic kidney disease as defined by KDIGO guidelines, renal transplant recipients, and those with incomplete clinical or laboratory data were excluded.

For the purpose of seasonal analysis, the study period was categorized into four distinct seasons based on regional climatic patterns: summer (March–June), monsoon (July–September), winter (October–February), and spring (February–March). Detailed demographic and clinical data were collected for each patient, including age, sex, underlying comorbidities, etiological factors contributing to AKI, and clinical outcomes. The etiology of AKI was determined based on clinical evaluation, laboratory investigations, and imaging findings, and categorized into major groups such as sepsis, dehydration, obstructive uropathy, acute glomerulonephritis, and others.

The severity of AKI was classified into three stages (Stage 1, Stage 2, and Stage 3) according to KDIGO staging criteria (1). Statistical analysis was performed using standard statistical software. Categorical variables were expressed as frequencies and percentages, and comparisons between groups were made using the chi-square test. Trend analysis was performed to evaluate seasonal variation in incidence, etiology, and severity of AKI. A p-value of less than 0.05 was considered statistically significant.

RESULTS

1. Seasonal Distribution

- Summer: 70 (35%)
- Monsoon: 60 (30%)
- Winter: 50 (25%)
- Spring: 20 (10%)

This demonstrates a bimodal peak, with highest incidence in summer and secondary peak in monsoon.

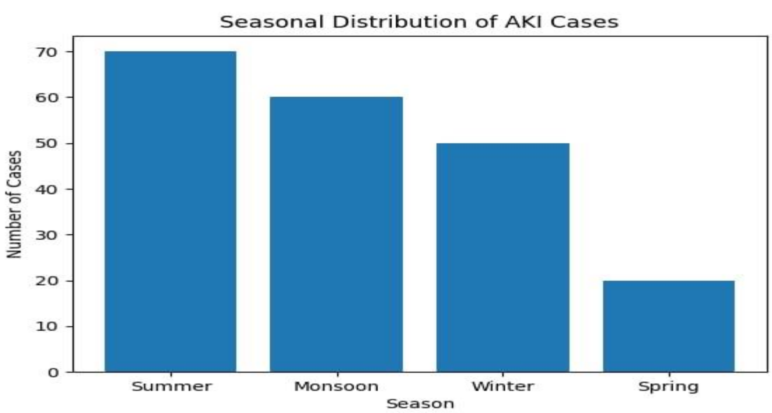

Figure 1 illustrates the seasonal distribution of acute kidney injury (AKI) cases observed in the study population. The x-axis represents the four predefined seasonal categories (summer, monsoon, winter, and spring), while the y-

axis indicates the number of AKI cases. The graph demonstrates a clear bimodal distribution, with the highest incidence recorded during summer (n = 70, 35%), followed by monsoon (n = 60, 30%), winter (n = 50, 25%), and spring (n = 20, 10%).

2. Seasonal Variation in Etiology (p < 0.001)

Etiology	**No Of Patients (%)**			
	Summer	**Monsoon**	**Winter**	**Spring**
Sepsis (n=68)	20 (28.57)	30 (50.00)	14 (28.00)	4 (20.00)
Dehydration (n=40)	28 (40.00)	6 (10.00)	4 (8.00)	2 (10.00)
Nephrotoxic drugs (n=28)	10 (14.29)	8 (13.33)	8 (16.00)	2 (10.00)
Cardiorenal syndrome (n=22)	6 (8.57)	8 (13.33)	6 (12.00)	2 (10.00)
Obstructive uropathy (n=18)	4 (5.71)	4 (6.67)	8 (16.00)	2 (10.00)
AGN (n=14)	2 (2.86)	2 (3.33)	8 (16.00)	2 (10.00)
Others (n=10)	0	2 (3.33)	2 (4.00)	6 (30.00)
Total Patients (n=200)	**70**	**60**	**50**	**20**
P-Value	**< 0.001**			

There was a highly significant association between season and etiology ($p < 0.001$). Sepsis was most commonly observed during the monsoon season (50%), indicating a strong link with seasonal infections. In contrast, dehydration predominated in summer (40%), likely due to increased heat exposure and fluid loss. During winter, relatively higher proportions of obstruction and acute glomerulonephritis (16% each) were noted. In spring, although the total number of cases was lower, other causes accounted for a higher proportion (30%).

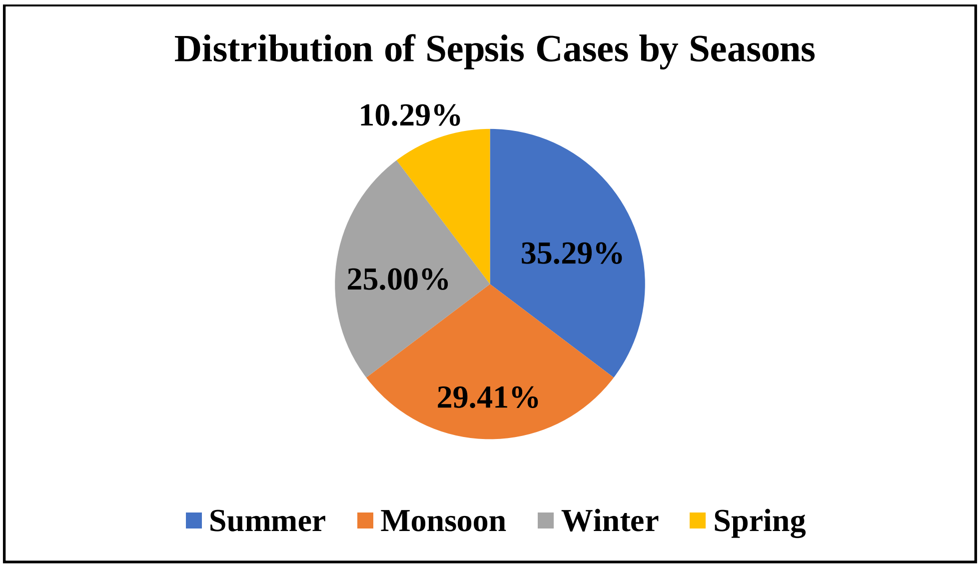

Fig:2. Distribution of Sepsis Cases by Seasons

Table:16. Seasonal Distribution of AKI Severity

Season	**AKI Severity-Number of Patients (%)**		
	Stage 1	**Stage 2**	**Stage 3**
Summer (n=70)	30 (41.67)	22 (34.38)	18 (28.13)
Monsoon (n=60)	15 (20.83)	20 (31.25)	25 (39.06)
Winter (n=50)	17 (23.61)	15 (23.44)	18 (28.13)
Spring (n=20)	10 (13.89)	7 (10.94)	3 (4.69)
Total	**72**	**64**	**64**
P VALUE	**0.17**		

In the present study, seasonal variation influenced the severity of AKI. During summer, most patients presented with Stage 1 AKI (42.9%), suggesting milder disease, likely due to dehydration. In contrast, monsoon season showed a higher proportion of severe AKI (Stage 3: 41.7%), possibly due to increased incidence of infections such as sepsis and leptospirosis. Winter demonstrated a relatively even distribution across all stages, while spring had predominantly mild cases (Stage 1: 50%).

DISCUSSION

The present study demonstrates a clear and clinically relevant seasonal variation in the incidence and etiology of acute kidney injury in a tropical tertiary care setting. Unlike observations from temperate regions, where AKI incidence typically peaks during winter months (11–13,15), our findings reveal a distinct bimodal distribution with a primary peak in summer and a secondary peak during the monsoon season. This divergence underscores the importance of geographical and climatic context in shaping the epidemiology of AKI. The summer peak is largely attributable to dehydration and volume depletion resulting from high ambient temperatures, leading predominantly to prerenal forms of AKI. In contrast, the monsoon peak appears to be driven by a surge in infectious diseases, with sepsis emerging as the leading etiology, reflecting the increased burden of waterborne and vector-borne infections during this period (10,14).

The strong association between season and etiology observed in this study highlights the interplay between environmental factors and disease mechanisms. The predominance of sepsis during the monsoon season is consistent with established patterns of infectious disease transmission in tropical regions, where heavy rainfall, poor sanitation, and water contamination contribute to increased infection rates (10,14). These infections often precipitate systemic inflammatory responses and hemodynamic instability, culminating in intrinsic renal injury. On the other hand, the high incidence of dehydration-related AKI during summer can be explained by excessive fluid loss, inadequate intake, and heat stress, which are common in regions with extreme temperatures. This also explains the observed trend toward milder AKI stages during summer, as prerenal injury is often reversible with timely fluid resuscitation.

Although a higher proportion of severe AKI (Stage 3) was observed during the monsoon season, the lack of statistical significance suggests that factors beyond season alone may influence disease severity. Potential explanations include the relatively modest sample size, overlapping etiologies, and variability in patient comorbidities and healthcare-seeking behavior. Nevertheless, the observed trend toward more severe disease during infection-prone periods is clinically meaningful and aligns with prior studies linking sepsis-associated AKI to worse outcomes (7–9).

When compared with global literature, our findings reinforce the concept of regional heterogeneity in AKI epidemiology. While studies from Europe and Japan have emphasized winter-associated AKI driven by cardiovascular and infectious triggers (11–13,15), the current study highlights the dominant roles of dehydration and infection in tropical climates. This has important implications for healthcare planning, as it suggests that preventive and management strategies must be tailored to local environmental conditions. For instance, public health interventions focusing on hydration awareness and heat mitigation may be particularly beneficial during summer months, whereas strengthening infection control measures and early sepsis management could help reduce AKI burden during the monsoon season (10,14).

From a clinical perspective, recognizing these seasonal trends can facilitate early diagnosis and risk stratification, enabling clinicians to anticipate common etiologies and initiate timely interventions. Furthermore, healthcare systems can use this information to optimize resource allocation, such as ensuring adequate availability of dialysis services and intensive care facilities during peak seasons. Despite its strengths, including a prospective design and comprehensive etiological assessment, this study is limited by its single-center nature and moderate sample size, which may affect generalizability. Future research should focus on multicenter cohorts and integration of climatic data to develop predictive models for AKI occurrence (15).

Overall, this study provides important insights into the seasonal dynamics of AKI in tropical settings and emphasizes the need for context-specific strategies to reduce its burden.

CONCLUSION

This study demonstrates that acute kidney injury (AKI) in tropical regions follows a distinct bimodal seasonal pattern, with peaks during summer and monsoon. Dehydration-driven prerenal AKI predominates in summer, while infection-related intrinsic AKI, particularly sepsis, is more common during the monsoon, highlighting the significant influence of environmental and infectious factors. Although seasonal variation in severity was not statistically significant, a higher proportion of severe AKI during the monsoon suggests a trend toward worse outcomes in infection-associated cases.

These findings underscore the importance of season-specific preventive strategies, including hydration measures during summer and infection control during monsoon, along with anticipatory healthcare resource allocation such as dialysis and critical care support. Despite limitations of a single-center design and moderate sample size, this study provides valuable insights into the seasonal epidemiology of AKI in tropical settings. Future multicenter studies incorporating climatic and socioeconomic variables are needed to develop predictive models and guide targeted interventions.

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