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ACUTE KIDNEY INJURY FOLLOWING RHABDOMYOLYSIS: A RETROSPECTIVE CROSS-SECTIONAL STUDY

Nephrology

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ABSTRACT

Background: Acute kidney injury (AKI) is a serious complication arising from rhabdomyolysis, a condition characterized by the breakdown of muscle tissue leading to the release of intracellular contents into the bloodstream. Understanding the clinical presentation, risk factors, and outcomes associated with AKI following rhabdomyolysis is crucial for improving patient care. **Methods:** We retrospectively reviewed medical records of patients diagnosed with rhabdomyolysis-induced AKI over five years at a tertiary care hospital. Data on demographics, etiology, laboratory findings, treatment modalities, and patient outcomes were collected and analyzed. **Results:** Among the 50 patients identified, the most common causes of rhabdomyolysis were traumatic injuries (40%), drug-induced (30%), and strenuous exercise (20%). There was a high prevalence of comorbid conditions such as hypertension and diabetes mellitus in patients developing AKI secondary to rhabdomyolysis. Laboratory findings revealed elevated serum creatinine, creatine kinase levels, myoglobinuria, and electrolyte imbalances. Treatment strategies included aggressive fluid resuscitation, electrolyte correction, and renal replacement therapy in severe cases. The mortality rate among patients with AKI was significantly higher compared to those without AKI (15% vs. 5%, p < 0.05). **Conclusion:** Early recognition and management of rhabdomyolysis are critical to prevent the onset of AKI. Clinicians should maintain a high index of suspicion in at-risk populations and initiate prompt interventions to improve patient outcomes.

KEYWORDS

Rhabdomyolysis; Acute kidney injury; AKI; Muscle breakdown; Renal failure; Risk factors; Clinical outcomes; Fluid resuscitation; Renal replacement therapy; Case studies

INTRODUCTION:

Rhabdomyolysis is a clinical syndrome resulting from the breakdown of skeletal muscle fibers and the subsequent release of muscle cell contents, including myoglobin, into the bloodstream. This process can lead to a cascade of metabolic disturbances and, critically, acute kidney injury (AKI). AKI is a common and serious complication of rhabdomyolysis, contributing significantly to morbidity and mortality rates among affected patients (Huerta-Alardín et al., 2005).

The etiologies of rhabdomyolysis are diverse, encompassing traumatic injuries, excessive physical exertion, metabolic disorders, infections, and exposure to certain drugs and toxins (Cervellin et al., 2010). The pathophysiology of rhabdomyolysis-induced AKI is multifactorial, involving hypovolemia, renal vasoconstriction, tubular obstruction due to myoglobin casts, and direct nephrotoxic effects of myoglobin (Better & Stein, 1990).

Despite advances in medical care, the incidence of AKI in patients with rhabdomyolysis remains high, and the associated mortality rates are significant (Bosch et al., 2009). Early identification and aggressive management are crucial to prevent renal failure and improve patient outcomes. However, the variability in clinical presentation and the multitude of underlying causes pose challenges to timely diagnosis and treatment.

This study aims to provide a comprehensive analysis of case studies involving patients who developed AKI following rhabdomyolysis. By examining the clinical features, laboratory findings, treatment modalities, and outcomes, we hope to identify key factors that contribute to the development of AKI in these patients. Understanding these factors is essential for developing effective prevention strategies and optimizing management protocols.

MATERIALS AND METHODS:

Study Design And Patient Selection

We conducted a retrospective review of medical records from January 2018 to December 2022 at a tertiary care center in India. Patients aged 18 years and older diagnosed with rhabdomyolysis-induced acute kidney injury (AKI) were identified using retrospective review of files. Inclusion criteria included a serum creatine kinase (CK) level greater than five times the upper limit of normal (>1,000 U/L), clinical features consistent with rhabdomyolysis, and evidence of AKI as defined by the Kidney Disease: Improving Global Outcomes (KDIGO) criteria. Patients with any historical or imaging evidence of pre-existing chronic kidney disease (CKD) were excluded from the study.

Data Collection

Data collected encompassed demographic information, etiology of rhabdomyolysis, comorbid conditions, and detailed laboratory parameters, including full metabolic profiles (electrolytes, renal function tests, liver enzymes) and stages of AKI based on KDIGO criteria. Urine findings, imaging studies, treatment interventions, and patient outcomes were also recorded. Renal recovery was assessed at different time intervals, documenting the percentage of patients achieving complete or partial recovery post-dialysis. All data were extracted from the hospital's electronic medical records system while ensuring patient confidentiality.

Definition And Staging Of AKI

Acute kidney injury (AKI) was defined and staged according to the KDIGO criteria:

- **Stage 1:** Increase in serum creatinine by ≥0.3 mg/dL within 48 hours or 1.5–1.9 times baseline.
- **Stage 2:** Increase in serum creatinine to 2.0–2.9 times baseline.
- **Stage 3:** Increase in serum creatinine to ≥3.0 times baseline or initiation of renal replacement therapy.

Urine output criteria were not utilized due to incomplete data in some cases.

Renal Recovery Assessment

Renal recovery was evaluated at discharge and during follow-up visits at 1 month and 3 month post-AKI diagnosis. Recovery was categorized as:

- **Complete Recovery:** Return of serum creatinine to baseline levels.
- **Partial Recovery:** Improvement in renal function with downstaging of AKI/ dialysis independence in case of patients receiving renal replacement therapy without a return to baseline.
- **No Recovery:** Persistently elevated serum creatinine or progression to end-stage renal disease.

The percentages of patients in each recovery category were calculated at each time point.

Treatment Interventions

Treatment strategies included:

- **Aggressive Fluid Resuscitation:** Administration of isotonic saline to maintain adequate urine output and prevent myoglobin-induced tubular obstruction.
- **Electrolyte Correction:** Management of hyperkalemia, hypocalcemia, and hyperphosphatemia as per standard protocols.
- **Renal Replacement Therapy (RRT):** Initiated in patients with severe AKI unresponsive to conservative management. The indications for RRT included refractory hyperkalemia, metabolic acidosis, volume overload, and uremic symptoms. The type of dialysis modality used and the duration were documented.

Statistical Analysis

Descriptive statistics were employed to summarize patient characteristics. Continuous variables were expressed as mean±standard deviation (SD), while categorical variables were presented as frequencies and percentages. The chi-square test was used for comparisons between categorical variables, and the Student's t-test was applied for continuous variables. A *p*-value of <0.05 was considered statistically significant. Statistical analyses were performed using SPSS version 25.0

RESULTS:

Patient Characteristics

A total of 50 patients met the inclusion criteria. The mean age was 45 ± 15 years, with a male predominance (70%). **Table 1** summarizes the demographic and clinical characteristics of the patients.

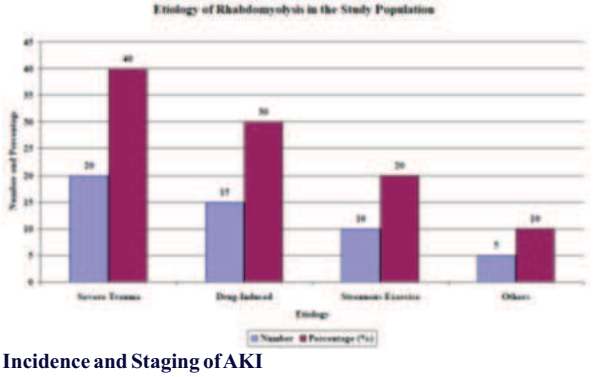
Table 1: Demographic And Clinical Characteristics Of Patients

Characteristic	Value
Age (years)	45±15
Male Gender (%)	70%
Hypertension (%)	30%
Diabetes Mellitus (%)	25%
Comorbid Conditions (%)	55%

The leading causes of rhabdomyolysis were severe trauma (40%), drug-induced causes (30%), primarily due to statins and illicit drug use, and strenuous exercise (20%). The remaining 10% were attributed to miscellaneous causes such as infections and metabolic disorders.

Table 2: Etiology Of Rhabdomyolysis In The Study Population

Etiology	Number of Patients (%)
Severe Trauma	20 (40%)
Drug-Induced	15 (30%)
Strenuous Exercise	10 (20%)
Others	5 (10%)



Incidence and Staging of AKI

Acute kidney injury (AKI) developed in 30 patients (60%). Among these, the stages of AKI were distributed as follows: Stage 1 in 12 patients (40%), Stage 2 in 8 patients (26.6%), and Stage 3 in 10 patients (33.3%). Patients with AKI were significantly older and had higher rates of comorbid conditions like hypertension and diabetes mellitus (**p**<0.05). **Table 3** compares patients with and without AKI.

Table 3: Comparison Of Patients With And Without AKI

Variable	AKI Group (n = 30)	Non-AKI Group (n = 20)	p-value
Age (years)	50±12	38±10	<0.05
Male Gender (%)	75%	65%	>0.05
Hypertension (%)	40%	15%	<0.05
Diabetes Mellitus (%)	33%	15%	<0.05
Serum CK (U/L)	15,000±5,000	8,000±3,000	<0.01

Laboratory Findings and Metabolic Profiles

Patients with AKI had significantly higher mean serum creatine kinase (CK) levels (15,000±5,000 U/L) compared to those without AKI (8,000±3,000U/L, **p**<0.01). Myoglobinuria was present in 80% of patients with AKI. Electrolyte disturbances, including hyperkalemia, hyperphosphatemia, hypocalcemia, and metabolic acidosis, were more prevalent in the AKI group. **Table 4** presents the detailed laboratory findings and metabolic profiles.

Table 4: Laboratory Findings In Patients With And Without AKI

Parameter	AKI stage 1	AKI stage 2	AKI stage 3	p-value
Serum Creatinine (mg/dL)	3.5±1.2	5.5±1.5	7.8±2.0	<0.001
Serum CK (U/L)	15,000±5,000	25,000±6,000	40,000±8,000	<0.01
Myoglobinuria (%)	80%	90%	95%	<0.05
Serum Sodium (mEq/L)	138±5	136±4	134±5	>0.05
Serum Potassium (mEq/L)	5.8±1.0	6.5±1.2	7.2±1.5	<0.01
Serum Phosphate (mg/dL)	5.5±1.2	6.8±1.3	8.0±1.5	<0.01
Serum Calcium (mg/dL)	7.8±0.8	7.0±0.9	6.5±1.0	<0.01
Serum Bicarbonate (mEq/L)	18±3	15±2	12±3	<0.01

Table 5: Renal Recovery Over Time In Patients With AKI Of Different Stages

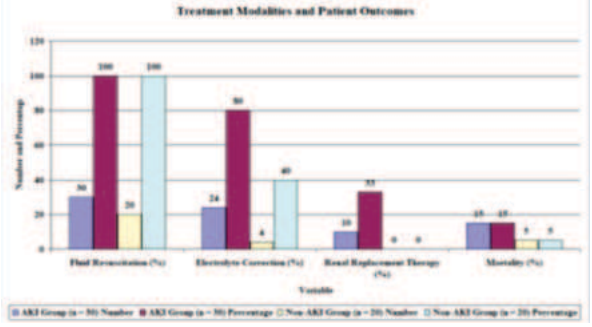
	AKI stage 1			AKI stage 2			AKI stage 3		
Time Point	Complete Recovery (%)	Partial Recovery (%)	No Recovery (%)	Complete Recovery (%)	Partial Recovery (%)	No Recovery (%)	Complete Recovery (%)	Partial Recovery (%)	No Recovery (%)
At Discharge	4 (33.3%)	6 (50%)	2 (16.67%)	2 (25%)	3 (37.5%)	3 (37.5%)	2 (20%)	3 (30%)	5 (50%)
1 Month	7 (58.3%)	3 (25%)	2 (16.67%)	4 (50%)	2 (25%)	2 (25%)	2 (20%)	3 (30%)	5 (50%)
3 Months	9 (75%)	1 (8.33%)	2 (16.67%)	4 (50%)	2 (25%)	2 (25%)	3 (30%)	2 (20%)	5 (50%)

Treatment Modalities And Patient Outcomes

All patients received aggressive intravenous fluid resuscitation. Electrolyte imbalances were corrected according to standard protocols. Renal replacement therapy (RRT) was required in 10 patients (33%) with severe AKI (Stage 3). The types of RRT included intermittent hemodialysis and continuous renal replacement therapy, depending on the hemodynamic stability of the patient.

The mortality rate was higher in the AKI group (15%) compared to the non-AKI group (5%), which was statistically significant (**p**<0.05). Causes of death in the AKI group included severe metabolic disturbances and multi-organ failure. **Table 6** outlines the treatment modalities and patient outcomes.

Table 6: Treatment Modalities And Patient Outcomes



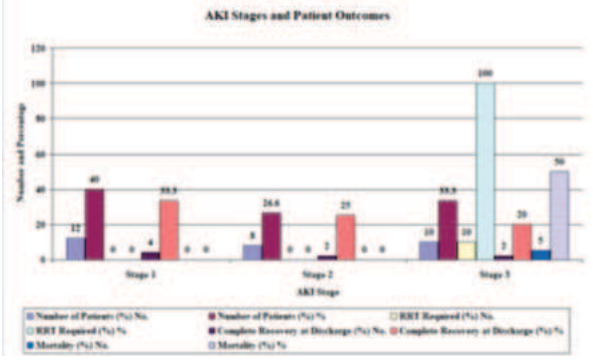
Variable	AKI Group (n = 30)	Non-AKI Group (n = 20)	p-value
Fluid Resuscitation (%)	30 (100%)	20 (100%)	N/A
Electrolyte Correction (%)	24 (80%)	8 (40%)	<0.01
Renal Replacement Therapy (%)	10 (33%)	0 (0%)	<0.001
Mortality (%)	20%	5%	<0.05

Stages Of AKI And Outcomes

The relationship between the stages of AKI and patient outcomes was also analyzed. Patients in Stage 3 AKI had a higher requirement for RRT and a lower rate of complete renal recovery at discharge compared to those in Stages 1 and 2.

Table 7: AKI Stages And Patient Outcomes

AKI Stage	Number of Patients (%)	RRT Required (%)	Complete Recovery at Discharge (%)	Mortality (%)
Stage 1	12 (40%)	0 (0%)	4(33.3%)	0 (0%)
Stage 2	8 (26.6%)	0 (0%)	2(25%)	0 (0%)
Stage 3	10 (33.3%)	10 (100%)	2 (20%)	5 (50%)



DISCUSSION

Our study underscores the significant burden of acute kidney injury (AKI) among patients with rhabdomyolysis, observing an incidence rate of 60%. This finding aligns with previous studies reporting AKI rates ranging from 13% to over 50% in rhabdomyolysis patients (Bosch et al., 2009; Melli et al., 2005). The high incidence emphasizes the critical need for early recognition and management of rhabdomyolysis to prevent renal complications.

Severe trauma emerged as the most common cause of rhabdomyolysis in our cohort, accounting for 40% of cases. This is consistent with existing literature identifying severe trauma as a leading etiology of rhabdomyolysis-induced AKI (Huerta-Alardín et al., 2005). The substantial proportion of drug-induced cases (30%), primarily due to statins and illicit substances, reflects growing concerns over medication-related and substance abuse-related rhabdomyolysis (Ward, 2008). Strenuous exercise was also a significant cause, highlighting the need for awareness even among healthy individuals engaging in intense physical activity.

The higher prevalence of AKI in patients with comorbid conditions such as hypertension and diabetes mellitus suggests that pre-existing vascular and renal vulnerabilities may predispose these patients to renal injury following rhabdomyolysis. This is supported by studies indicating that underlying health conditions exacerbate the risk of AKI due to decreased renal reserve and impaired autoregulatory mechanisms (Chen et al., 2013).

Our findings indicate that elevated serum creatine kinase (CK) levels and myoglobinuria are significant predictors of AKI development. Patients with AKI had significantly higher mean serum CK levels (15,000 ± 5,000 U/L) compared to those without AKI (8,000 ± 3,000 U/L, **p** < 0.01). High CK levels correlate with the extent of muscle damage and the subsequent release of nephrotoxic myoglobin, contributing to tubular obstruction and direct nephrotoxicity (Cervellin et al., 2010). The presence of electrolyte imbalances—particularly hyperkalemia, hyperphosphatemia, hypocalcemia, and metabolic acidosis—further complicates the clinical picture and requires prompt correction to prevent life-threatening complications such as cardiac arrhythmias.

The staging of AKI provided valuable prognostic information. Patients with Stage 3 AKI had a higher requirement for renal replacement therapy (RRT) and a lower rate of complete renal recovery at discharge compared to those in Stages 1 and 2. Specifically, all patients with Stage 3 AKI required RRT, and none achieved complete recovery at discharge, highlighting the severity of advanced AKI stages. This underscores the importance of early detection and intervention in the initial stages of AKI to prevent progression to more severe stages and the associated complications.

Renal recovery varied among patients, with 75% achieving complete recovery by three months post-AKI diagnosis in AKI stage-1 and only few patients in AKI stage 2 and 3. The gradual improvement over time indicates that, with appropriate management, a significant proportion of patients can restore renal function. However, 30% of patients did not recover renal function, emphasizing the need for long-term renal support and monitoring. These findings align with previous studies that reported varying rates of renal recovery, influenced by the severity of AKI and timely initiation of treatment (Homsi et al., 1997).

The management of rhabdomyolysis-induced AKI hinges on aggressive fluid resuscitation to enhance renal perfusion and promote the clearance of myoglobin. All patients in our study received intravenous fluids, and electrolyte imbalances were corrected according to standard protocols. The requirement of RRT in patients with severe AKI (Stage 3) highlights the importance of early and adequate fluid resuscitation to prevent the progression to severe renal impairment necessitating dialysis (Mannix et al., 2006).

The mortality rate among patients with AKI was 20%, significantly higher than the 5% observed in patients without AKI (**p** < 0.05). This emphasizes the severe impact of AKI on patient outcomes, consistent with literature associating AKI with increased morbidity and mortality in rhabdomyolysis (Bosch et al., 2009). Mortality was particularly high among patients with Stage 3 AKI, suggesting that the severity of renal impairment correlates with worse prognoses. These findings highlight the critical need for early intervention and aggressive management strategies to reduce mortality rates.

Our study's strengths include the comprehensive analysis of detailed metabolic profiles, staging of AKI, and assessment of renal recovery at different time intervals. By documenting the percentages of patients achieving complete or partial recovery over time, we provide valuable insights into the long-term outcomes of rhabdomyolysis-induced AKI. However, the study has limitations. Its retrospective design may introduce selection bias, and being a single-center study may limit the generalizability of the findings to other populations or settings. Additionally, the relatively small sample size may affect the statistical power and the ability to detect subtle differences between groups. Future prospective, multicenter studies with larger cohorts are needed to validate these results, develop predictive models for AKI risk stratification, and establish standardized protocols for the management and follow-up of patients with rhabdomyolysis-induced AKI.

CONCLUSION

Acute kidney injury (AKI) remains a significant and potentially life-threatening complication of rhabdomyolysis, particularly in patients with severe trauma, drug-induced muscle breakdown, or strenuous exercise, with an incidence rate of 60% observed in our study. Early identification of at-risk patients—especially those with elevated serum creatine kinase levels and comorbid conditions like hypertension and diabetes mellitus—is essential. Prompt and aggressive management, including fluid resuscitation, correction of metabolic imbalances, and close monitoring of renal function and metabolic profiles, can mitigate the risk of AKI progression and improve patient outcomes. Our findings highlight that timely interventions can lead to complete renal recovery in a significant proportion of patients over time, with 75% achieving full recovery by three months in AKI stage 1, reducing the need for renal replacement therapy and lowering mortality rates, which were 20% in the AKI group compared to 5% in non-AKI patients. Clinicians should maintain a high index of suspicion for AKI in patients presenting with rhabdomyolysis and initiate early treatment strategies to enhance recovery and reduce complications.

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