



Short Paper

Clinical outcomes of rhabdomyolysis & validation of McMahon Score for risk prediction

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Background & objectives: Rhabdomyolysis in tropics has a unique aetiology and clinical profile. The objective of this study was to determine the aetiology and clinical outcomes of rhabdomyolysis and validate the McMahon risk prediction score in affected individuals from south India.

Methods: A retrospective study of affected individuals with rhabdomyolysis admitted to a tertiary care hospital in south India, between January 2015 and June 2020, was undertaken. In-patients who were ≥ 15 yr in age and had creatinine phosphokinase ≥ 5000 U/l were included in the study. Cardiac, stroke, chronic muscular diseases and chronic kidney disease on maintenance haemodialysis were excluded. The incidence of acute kidney injury (AKI) in this group was calculated. Other clinical outcomes determined were 28-day mortality, proportion of individuals who required renal replacement therapy (RRT), intensive care unit (ICU) admission, vasopressors, mechanical ventilation (MV), number of days on mechanical ventilator and length of stay in ICU and hospital. Validation of McMahon risk prediction score for the requirement of RRT and mortality was performed.

Results: Major aetiologies identified in the 75 study participants included were infections, trauma and seizures. Twenty eight-day mortality was 24 per cent (n=18). AKI incidence was 68 per cent, out of which 43.1 per cent had RRT. AKI in all survivors became dialysis independent. Vasopressors, MV and ICU requirement were 30.7, 32 and 77.3 per cent, respectively. Receiver operator characteristic curve for RRT and mortality risk prediction based on the McMahon Score showed a sensitivity of 71.4 per cent and specificity of 77.8 per cent for a cut-off ≥ 7.8 .

Interpretation & conclusions: Rhabdomyolysis in tropics is associated with significant organ dysfunction and mortality. Although the incidence of AKI and RRT is high, the overall renal outcome is good among survivors. The wide confidence intervals for the area under curve for McMahon Score limit its predictability for RRT and mortality.

Key words Acute kidney injury - creatinine kinase - creatinine phosphokinase - McMahon Score - rhabdomyolysis

Rhabdomyolysis is a condition in which breakdown of striated muscles results in a wide range of clinical presentations from asymptomatic elevation of muscle enzymes to life-threatening disorder¹⁻³. Myoglobin

along with hypovolaemia, disseminated intravascular coagulation and compartment syndrome lead to acute kidney injury (AKI)^{4,5}. Rhabdomyolysis is a cause for 5-25 per cent of AKI cases¹, at times requiring renal

replacement therapy (RRT) and electrolyte disturbances. Hyperphosphataemia can result in hypocalcaemia through various mechanisms. Hyperkalaemia and hypocalcaemia can cause arrhythmia.

Rhabdomyolysis in individuals from tropical regions, with a higher incidence of sepsis and tropical diseases, have different clinical outcomes compared to those from temperate regions⁶⁻⁸. Data available from the tropics are limited. Available south Indian data showed an aetiological profile different from western literature and included snake envenomation, sepsis and trauma as common causes^{9,10}. This study aimed to get an insight into the disease characteristics in south India.

Multiple aetiologies associated with rhabdomyolysis might influence the incidence of AKI, RRT and mortality. In 2013, the McMahon scoring system, factored in the varying aetiologies along with other criteria for RRT and mortality risk prediction on admission in rhabdomyolysis¹¹. Prompt correction of the underlying cause and vigorous volume repletion is important in rhabdomyolysis⁵. Risk stratification of cases for intensive care unit (ICU) admission using prediction scoring systems is imperative in resource-limited communities¹². McMahon score has been validated in certain populations which are different from south India (Boston, Massachusetts and Cambridge, UK)^{11,13}. The primary objective of this study was to estimate the incidence of AKI in individuals diagnosed with rhabdomyolysis admitted to a tertiary care centre over a six-year period. The secondary objectives were to determine the mortality, to validate a risk prediction score for the requirement of RRT and mortality and to determine the proportion of individuals who required RRT, ICU admission, vasopressors, mechanical ventilation (MV), number of days on mechanical ventilator, length of stay (LOS) in ICU and hospital in this study group.

Material & Methods

A retrospective study of all individuals admitted to Pushpagiri Medical College Hospital, Thiruvalla, Kerala, between January 2015 and June 2020 who were diagnosed with rhabdomyolysis was performed. Study setting was a tertiary teaching hospital which has a case mix of trauma, post-operative and medical cases. The Institutional Review Board, Pushpagiri Group of Institutions, granted ethics approval for this study. Informed consent was waived in view of retrospective study design. Data were anonymized before analysis was performed.

Data Collection: Data on demographics, clinical characteristics, laboratory values and outcomes were collected by medical record review. Inclusion criteria were age ≥ 15 yr and creatinine phosphokinase (CPK) values ≥ 5000 U/l. Cardiac, stroke and chronic muscular diseases can produce CPK isoenzymes¹⁴ and were, therefore, excluded from the study. Individuals with chronic kidney disease (CKD) on maintenance dialysis were also excluded. Data regarding the sequential organ failure assessment (SOFA) score on admission, initial serum CPK, calcium, phosphorus, uric acid, potassium, initial and peak serum creatinine were collected. Outcome variables included incidence of AKI, oliguria, requirement for RRT, MV, vasopressors and ICU admission. Number of days of MV, LOS in ICU, LOS in hospital and 28-day mortality were also included as outcomes. Multiple aetiologies based on previous rhabdomyolysis-related literature were recorded for individuals if identified and categorized into groups. McMahon Score was calculated for all except those with CKD and < 18 yr of age, as per the criteria originally devised in the scoring system.

AKI was defined as serum creatinine rise by ≥ 0.3 mg/dl in 48 h or a rise of ≥ 1.5 times the baseline, which is known or presumed to have occurred within the prior seven days or more than six hours of urine volume < 0.5 ml/kg/h, based on the Kidney Disease Improving Global Outcomes¹⁵. All individuals with CKD included in the study were previously diagnosed with CKD but not requiring maintenance dialysis. Of these, those who had increased serum creatinine above their baseline or whose values decreased below the admission value after recovery were considered as having AKI. Serum creatinine returning to baseline values with no further requirement of RRT was considered as AKI recovery. Oliguria was defined as urine output < 0.5 ml/kg for six hours or more. RRT was initiated by the nephrologist based on indicators such as hyperkalaemia, metabolic acidosis and fluid overload.

In individuals who had elevated serum creatinine levels at the time of discharge, laboratory values during subsequent clinic visits were collected from the hospital information system till creatinine normalized. In addition, data were collected telephonically. Data on normalization of creatinine, cessation of RRT and 28-day mortality were collected in this fashion.

Statistical analysis: Descriptive statistics used individual mean with standard deviation, median with interquartile range (IQR) or frequency and percentage.

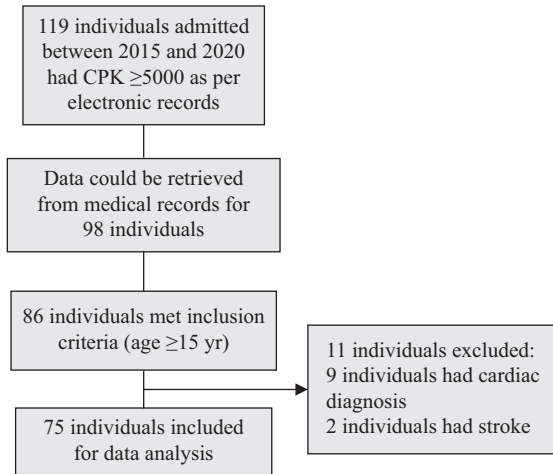


Fig. 1. Participant selection. CPK, creatinine phosphokinase in U/l.

Comparison of outcome variables between the groups, with and without AKI, was performed. Chi-square test was done to find out whether there is a significant difference between requirement of vasopressors, MV and ICU admission for the AKI and non-AKI groups. Non-parametric Mann-Whitney *U* test was done to compare the number of days of MV, LOS in ICU and LOS in hospital in the AKI and non-AKI groups. Receiver operating characteristic (ROC) graphs were plotted for McMahon Score. Area under the curve (AUC) was calculated to assess the diagnostic accuracy of McMahon Score in detecting AKI requiring RRT and mortality in rhabdomyolysis and to assess the optimal cut-off scores. For all statistical interpretations, $P < 0.05$ was considered significant. Analysis was performed using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp. NY, USA).

Results & Discussion

This study was undertaken in the State of Kerala, south India, with a high, health awareness and easy accessibility to healthcare¹⁶. In general, individuals sought medical advice early in the course of the illness. Seventy-five individuals were enrolled in the present study as per the inclusion and exclusion criteria (Fig. 1). Of these, three participants who were < 18 yr were included in all analyses except calculation of McMahon score.

Published studies have reported varying levels of CPK values for diagnosis of rhabdomyolysis¹⁴. Conventional diagnostic criterion for rhabdomyolysis includes CPK value five times more than the normal upper limit or ≥ 1000 U/l^{5,14}. CPK ≥ 5000 U/l has been

used in recent research as an inclusion cut-off^{4,11}. For this study, we chose a cut-off of ≥ 5000 U/l, considering the endemicity of tropical infections in the region. Since leptospirosis, dengue and other viral infections can cause serum CPK elevation, we presumed that a higher CPK cut-off will highlight the clinically significant cases with rhabdomyolysis.

Aetiological factors were categorized into six broad groups (Table I). Infections and crush injury following trauma accounted for 29.3 and 20 per cent, respectively. Other common medical causes were seizures (17.3%) and neuroleptic malignant syndrome (NMS) (16%). Leptospirosis ($n=8$) and dengue ($n=3$), common in tropical areas, were present. Antipsychotic intake was frequently observed in individuals diagnosed with NMS. Table II shows the clinical and laboratory variables of the study participants.

Multiple medical causes for rhabdomyolysis were often found in our study sample^{5-7,9,17,18}. Individuals with leptospirosis, dengue and bacterial infections had other coexisting causal factors, contributing to rhabdomyolysis. Two out of the three cases of dengue in our study sample were on antipsychotics and had diagnosis of NMS. Four cases were parkinsonism with intercurrent illness, diagnosed with parkinsonism hyperpyrexia syndrome¹⁹. Two cases of methanol poisoning, classified under toxins, turned out to be fatal. Bacterial and tropical infections together accounted for a larger proportion in comparison to 13 per cent in the literature⁶. Alcohol withdrawal was eight per cent compared to a reported 15 per cent⁶. Although immobilization was the most common aetiology in many studies (Candela *et al*⁴ 33.8%, Melli *et al*²⁰ 18% and Vangstad *et al*⁶ 60%), a lower proportion was identified in this study (6.7%). There was only one case of snake envenomation (classified as toxin), unlike other studies from India^{9,10}.

Outcomes: The incidence of AKI was 68 per cent (51/75) (Table III). 47.1 per cent had oliguria and 43.1 per cent required RRT. 62 per cent (28/45) belonged to stage 3 AKI (Table IV). All individuals with AKI who survived were dialysis independent at discharge with a mean serum creatinine of 0.94 mg/dl. Those with CKD ($n=6$) had acute worsening of kidney injury as suggested by elevation of creatinine from baseline with demonstrated AKI recovery after treatment, besides high CPK values and presence of aetiologies associated with rhabdomyolysis.

Different definitions of AKI as well as inclusion criteria for CPK were used in several studies with the

Table I. Distribution of aetiology and outcomes

Aetiology	Total (n=75), n (%)	AKI (n=51), n (%)	RRT (n=22), n (%)	Mortality (n=18), n (%)
Trauma (crush injury)	15 (20)	9 (17.6)	2 (9.1)	3 (16.7)
Muscular overactivity	48 (64)	30 (58.8)	12 (54.5)	11 (61.1)
Seizure	13 (17.3)	9 (17.6)		
NMS	12 (16)	6 (11.8)		
Exertion	7 (9.3)	4 (7.8)		
Alcohol withdrawal	6 (8)	3 (5.9)		
Spasticity	1 (1.3)	1 (2)		
Immobilization	5 (6.7)	4 (7.8)		
Parkinsonism hyperthermia syndrome	4 (5.3)	3 (5.9)		
Infections	22 (29.3)	20 (39.2)	8 (36.4)	6 (33.3)
Bacterial/virus	11 (14.7)	10 (19.6)		
Leptospirosis	8 (10.7)	8 (15.7)		
Dengue	3 (4)	2 (3.9)		
Drugs and toxins	9 (12)	5 (9.8)	5 (22.7)	3 (16.7)
Toxins	5 (6.7)	2 (3.9)		
Statin myopathy	3 (4)	3 (5.9)		
Anabolic steroid	1 (1.3)	0		
Ischaemia	3 (4)	1 (2)	1 (4.5)	0
Miscellaneous	3 (4)	2 (3.9)	1 (4.5)	0
Hypothyroidism	1 (1.3)	1 (2)		
Thyrotoxicosis	1 (1.3)	1 (2)		
Severe pancreatitis	1 (1.3)	0		

Aetiology was multifactorial in each individual. Hence, the above variables are not mutually exclusive. AKI, acute kidney injury; RRT, renal replacement therapy; NMS, neuroleptic malignant syndrome

Table II. Clinical characteristics of the study sample

Clinical and laboratory variables	Total (n=75)
Age (yr), mean±SD	48.6±18.3
Gender (male: female)	66:9
CPK value (U/l), median (IQR)	11,760 (7355-24,170)
Initial creatinine (mg/dl), median (IQR)	1.4 (0.8-2.5)
Peak creatinine (mg/dl), median (IQR)	2 (0.9-4.2)
Potassium (mg/dl), median (IQR)	4 (3.7-4.1)
Calcium (mg/dl), median (IQR)	8.1 (7.9-8.5)
Phosphorus (mg/dl), median (IQR)	2.7 (1.9-5)
Uric acid (mg/dl), median (IQR)	2.8 (2.4-3.6)
Initial SOFA score, median (IQR)	4 (2-6)
Diabetes mellitus, n (%)	16 (21.3)

IQR, interquartile range; SD, standard deviation; CPK, creatinine phosphokinase; SOFA, sequential organ failure assessment

Table III. Clinical outcomes of the study sample

Outcome variables	Total (n=75), n (%)
AKI	51 (68)
Oliguria (n=51)	24 (47.1)
RRT (n=51)	22 (43.1)
Vasopressor requirement	23 (30.7)
Mechanical ventilation requirement	24 (32)
ICU requirement	58 (77.3)
Days on mechanical ventilation, mean±SD	2.09 (4.074)
LOS in ICU (days), median (IQR)	5 (1-7)
LOS in hospital (days), median (IQR)	8 (5-15)
Mortality	18 (24)

ICU, intensive care unit; LOS, length of stay

end result of variable AKI incidence (17-65%) and RRT requirement (8-65%)^{4,6}. AKI can be multifactorial.

Bacterial sepsis, leptospirosis and hypotension can result in AKI, in the absence of rhabdomyolysis²¹. A higher CPK value was presumed to exclude such cases.

Table IV. Clinical outcomes for different stages of acute kidney injury (AKI)

Outcome variables	Stage 1 (n=9)	Stage 2 (n=8)	Stage 3 (n=28)
LOS in ICU (days), median (IQR)	8 (4-13)	5 (3.75-7.5)	5 (2-7)
LOS in hospital (days), median (IQR)	10 (7-13)	8.5 (4-17)	6.5 (3-13.3)
Mortality, n	2	1	14

Table V. Comparison of outcome variables in acute kidney injury and non-acute kidney injury groups

Outcome variables	No AKI (n=24), n (%)	AKI (n=51), n (%)	P	Relative risk
Vasopressor requirement (n=23)	3 (12.5)	20 (39.2)	0.019	3.14 (1.03-9.54)
Mechanical ventilation requirement (n=24)	4 (16.7)	20 (39.2)	0.051	2.35 (0.9-6.13)
ICU requirement (n=58)	13 (54.2)	45 (88.2)	0.001	1.63 (1.11-2.38)
Days on mechanical ventilation, mean±SD	1.21 (3.22)	2.51 (4.39)	0.071	
LOS in ICU (days), median (IQR)	5 (0-7)	5 (2-7)	0.137	
LOS in hospital (days), median (IQR)	8.5 (5-19)	8 (5-14)	0.303	

P<0.05 is taken as significant. CKD individuals excluded from the comparison. CKD, chronic kidney disease

The AKI group was more associated with hypotension and vasopressor requirement than non-AKI. There was no documented cause for AKI available from medical records other than those documented as aetiological factors of rhabdomyolysis.

The incidence of vasopressor, MV and ICU requirements among the 75 study participants was 30.7, 32 and 77.3 per cent, respectively (Table III). The mean (SD) number of days of MV was 2.09 (4.074). The median (IQR) for LOS in ICU and LOS in hospital was five (1-7) and eight (5-15) days, respectively.

In a multicentre retrospective study by Candela *et al*⁴ in 2020, involving 387 individuals with CPK >5000, 315 (81.4%) developed AKI and 103 (26.6%) required RRT. Crush syndrome (27.9%) and vascular ischaemia (18.3%) were the major causes of rhabdomyolysis in this cohort. 47.8 per cent and 59.1 per cent required vasopressors and MV, respectively. A 28-day mortality rate in this group was relatively low, 10.9 per cent. In comparison, our study sample had 20 per cent trauma cases with crush injury, AKI incidence was less (68%), need for RRT was higher (29.3%) and 28-day all-cause mortality was also higher (24%). Lesser number of participants required vasopressors (30.7%) and MV (33.3%). Discontinuation of RRT observed in all AKI cases in this study is in concordance with previous research^{9,22,23}. Vangstad *et al*⁶ reported an AKI incidence of 51 percent, out of which 20 per cent required RRT. In a prospective trial

from south India recruiting 90 trauma cases with CPK >5000U/l, AKI incidence and mortality were 15.55 and 30 per cent, respectively²⁴.

The comparison of outcome variables between the two groups, AKI and non-AKI, is shown in Table V. Vasopressor and ICU requirement was more in the AKI group than in the non-AKI group. More participants with AKI required MV than those without AKI although the difference was not significant. RRT was required in 67 per cent of oliguric individuals compared to non-oliguric (21%).

Myoglobin is probably the key element causing AKI^{9,10}. However, its levels may vary and even be absent based on the time of testing^{14,22,25}. This is because serum myoglobin levels peak early in the course of the illness compared to CPK value (30 vs. 72 h) and has a rapid metabolism within 6-8 h (half-life of myoglobin 2-4 h vs. CPK 1.5 days)⁷. Serum myoglobin-CPK ratio was shown to better predict AKI than CPK alone^{6,7}. For these reasons, CPK values were not analyzed.

Mortality: Twenty-eight-day all-cause mortality was 24 per cent (18/75). A majority of the participants who died had community or hospital-acquired sepsis and multiorgan dysfunction. Among these, all except one had AKI, 38 per cent (7/18) needed vasoactive drugs and 72 per cent (13/18) were mechanically ventilated. The median (IQR) time to death from the inciting aetiology was six (3.5-10) days. Rhabdomyolysis in sepsis portends poor prognosis²⁶. Literature review

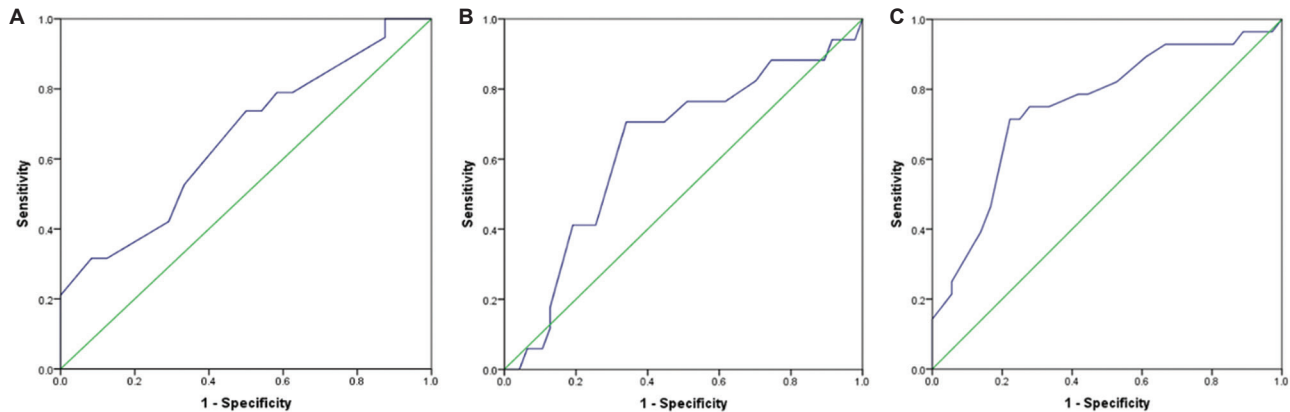


Fig. 2. ROC curve based on McMahon score. (A) ROC curve for RRT. (B) ROC curve for mortality. (C) ROC curve for aggregate. AUC, area under curve; ROC, receiver operator characteristic; RRT, renal replacement therapy.

reports varied mortality rates for rhabdomyolysis, 3.4-59 per cent^{4,6,22,24}. Mortality depends on the diagnostic CPK value, the presence of AKI, the severity of underlying illness and coexisting diseases⁶.

The median McMahon score was 7 (IQR: 4-9.4). A cut-off of ≥ 7.8 on ROC curve for McMahon score showed 71.4 per cent sensitivity and 77.8 per cent specificity for predicting aggregate of RRT and mortality (AUC: 0.752, CI: 0.629-0.876, OR=8.75). The same cut-off showed 73.7 per cent sensitivity and 50 per cent specificity for predicting RRT and 70.6 per cent sensitivity and 66 per cent specificity (AUC:0.636, CI:0.479-0.794; OR=4.65) for mortality prediction (Fig. 2A-C). A study comparing CPK and McMahon Score revealed that McMahon Score of ≥ 6 was 86 per cent sensitive and 68 per cent specific for RRT prediction¹³. However, this study was done in neurosciences and trauma units and hence different from the present study group in that, the majority of cases were trauma (76%) and vascular ischaemia. A higher cut-off score in the present study indicates, that participants who required RRT or died were sicker. This may be contributed to the advancement in the medical management of critically ill, including early fluid resuscitation in the last decade.

Limitations of the study include a small sample size and the retrospective design. The presence of coexisting causal factors other than those documented could not be ruled out. Furthermore, selection bias is possible, as we decided to focus on a higher CPK value as the criteria for inclusion. The presence of myoglobin casts in individuals with CPK<1500U/l has been demonstrated in another study⁹, albeit, in smaller numbers. The unavailability of serum

myoglobin test in the study hospital precluded its inclusion in the analysis. However, serum myoglobin is not a sensitive test for rhabdomyolysis^{14,22,25}. Urine myoglobin test was negative in many participants, probably due to the transient nature of myoglobinuria. Isolated CPK values have not been found to be predictive of the need for RRT or mortality in recent studies and therefore were not analyzed separately in this study^{11,13,24}. AUC for McMahon Score had wider confidence intervals, thereby limiting predictability for RRT and mortality.

The strength of the study is that it looked into AKI incidence, mortality and the degree of organ support required in rhabdomyolysis and attempted to validate a risk prediction score with an aim to prioritize care. A higher CPK cut-off was helpful in selection of cases which need more diligent attention. Medicine practice in resource-crunched settings often translates to higher reliance on clinical inputs based on pre-test probability with limited investigations. A sound knowledge of the common aetiological factors and outcomes of rhabdomyolysis in the region will go a long way in prompt recognition and appropriate management in such challenging scenarios.

Overall, in this study, the cut-off value for McMahon Score was higher than previously observed, although, with uncertain predictability for RRT and mortality because of the wide confidence intervals. Additional studies might be required for risk prediction in rhabdomyolysis. Overall, the findings of the present study suggest that the renal outcome is good among survivors. The diverse multifactorial causes of rhabdomyolysis necessitate a high degree of suspicion for its diagnosis. This study provides a perspective on

the clinical spectrum of rhabdomyolysis to clinicians in similar settings.

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Conflicts of Interest: None.

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