Original Article

Clinical presentation and outcomes of patients with rhabdomyolysis

A tertiary care center experience

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ABSTRACT

الأهداف: تقييم المظاهر السريرية والنتائج للمرضى الذين يعانون من انحلال الربيدات في المجتمع السعودي.

المنهجية: دراسة وصفية بأثر رجعي للمرضى البالغين الذين أصيبوا بانحلال الربيدات ومثلوا للعلاج في مدينة الملك عبد العزيز الطبية خلال الفترة من يناير 2016 حتى ديسمبر 2022.

النتائج: شملت الدراسة 58 مريضا. كان معظم المشاركين (84.5%) من الذكور بمتوسط عمر 41 سنة. شكلت الأدوية، وخاصة الستاتين (22.4%) والعقاقير غير المشروعة (15.5%)، غالبية أسباب انحلال الربيدات ضمن المجموعة. الشكوى الأكثر شيوعا هي الألم العضلي (63.8%)، يليه التعب (37.9%). أكثر من ثلث المشاركين (32.8%) عانوا من إصابة حادة في الكلى، واحتاج 3 منهم للغسيل الكلوي المؤقت. كان معدل الدخول في وحدة العناية المركزة 17.2% (10 مرضى)، وبلغ معدل الوفاة الإجمالي 8.6%. المرضى الذين عانوا من المضاعفات كان لديهم انخفاض كبير في وظائف الكلى، وكان لديهم مستويات أعلى من نتتروجين اليوريا في الدم والفجوة الأنيونية وحمض البوليك.

الخلاصة: تقدم هذه الدراسة نظرة شاملة للسمات السريرية والمخبرية، وأسباب، ومضاعفات، ونتائج انحلال الربيدات بين المرضى السعوديين، مما يوفر أساسا للبحث المستقبلي.

Objectives: To evaluate the clinical and laboratory features, complications, and outcomes of patients with rhabdomyolysis in the Saudi population.

Methods: Retrospectives descriptive study of adult patients who presented to King Abdulaziz Medical City (KAMC) withrhabdomyolysis between January 2016 and December 2022.

Results: Most of the participants (84.5%) were male, with a median age of 41 years and a body mass index of 26.5 kg/m^2. Medications, mainly statins (22.4%) and illicit drugs (15.5%), constituted the root causes of rhabdomyolysis in the cohort (44.8%). The most common presenting complaints were myalgia (63.8%) and fatigue (37.9%). More than one-third of the participants (32.8%) developed AKI, with 3 patients requiring temporary hemodialysis, and only 8.6% developed acute liver failure (ALF). Intensive care unit (ICU) admission was required for 10 patients (17.2%), and the overall mortality rate was 8.6%. Patients who developed complications (composite outcomes of AKI, ALF, multiorgan failure, or death) had significantly reduced kidney function and higher levels of blood urea nitrogen, anion gap, and uric acid upon admission than those who did not.

Conclusion: This study offers a thorough understanding of clinical and laboratory features, causes, complications, and outcomes of rhabdomyolysis among Saudi patients. The insights gained enhance our understanding of rhabdomyolysis within this population, providing a foundation for future research and improvements in clinical management.

Keywords: rhabdomyolysis, acute kidney injury, creatine phosphokinase, myopathy, muscle damage

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Rhabdomyolysis (RML) is characterized by striated muscle necrosis resulting in various forms of systemic manifestations, of which acute kidney injury (AKI), electrolyte imbalance, and disseminated intravascular coagulation are the most important.[1] Manifestations of RML are contingent upon the degree of muscle damage, ranging from a predominantly asymptomatic illness with isolated elevation of serum creatine phosphokinase (CPK) to life-threatening emergencies, such as cardiac arrhythmias, AKI, compartment syndrome, and disseminated intravascular coagulation.[1,2] While the exact global incidence of RML is uncertain, morbidly obese, elderly, African American, and post-operative individuals, as well as chronic users of lipid-lowering drugs were identified to be particularly high-risk populations.[3] Similarly, few population-based studies have examined the incidence and prevalence of RML within Saudi Arabia specifically.[4]

Despite the significance of RML, an internationally agreed-upon definition of the condition is lacking. Since an elevated CPK level is the most sensitive laboratory test for assessing muscle injury, a recent systematic review evaluated variations in cut-off values for RML diagnosis; the researchers found that a CPK value of >1000 IU/L or serum CPK levels greater than 5 times the upper limit of the normal level were the most frequently used thresholds to define RML.[5]

The etiology of RML varies with age and can be classified based on the underlying mechanism of injury or on whether the cause is physical/non-physical, exertional/non-exertional, or acquired/inherited.[3] Trauma, viral infections, drug reactions, and physical exertion are often implicated in pediatric cases, while trauma, drug usage, and infections are commonly reported etiologies among adult patients.[6-12] Several case reports identify certain rare etiologies for RML, such as glycine use for bladder irrigation and human stampede.[13,14]

Acute kidney injury is a serious potential complication of RML and is associated with increased mortality, with an incidence of between 37.8% and 81.4% in patients with RML.[15-17] An epidemiological study of AKI causes in Saudi Arabia showed that of 150 patients admitted with AKI, 10.7% was due to RML, mainly related to road traffic accidents, which have become more frequent in the country.[4] The lack of regional epidemiological data on RML necessitates further research. Hence, in this article, we aimed to examine the clinical and laboratory features, complications, and outcomes of patients with RML in one of the largest tertiary centers in Saudi Arabia. By conducting this study, we seek to enhance our understanding of RML within the Saudi population and to contribute to existing knowledge pertaining to this condition.

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Methods. This retrospective descriptive study took place in the Department of Medicine, King Abdulaziz Medical City (KAMC), one of the largest publicly funded tertiary hospital in Riyadh, Saudi Arabia. The Institutional Review Board of King Abdullah International Medical Research Center, Ministry of National Guard-Health Affairs, Riyadh, Kingdom of Saudi Arabia granted approval for the study (NRC22R/561/11). The study complies with the principles of Helsinki Declaration.

All adults aged ≥18 years old who presented to KAMC with RML between January 2016 and December 2022 were included in the study. Patients with an underlying genetic cause of myopathy, acute myocardial infarction at the time of presentation, and end-stage kidney disease (both dialysis-dependent and kidney transplant recipients) were excluded from the study.

The relevant data were obtained by scrutinizing electronic health record (EHR) at KAMC, "BestCare" (Seoul, South Korea: ezCaretech). The gathered data encompassed age, gender, body mass index (BMI), comorbidities (such as diabetes mellitus [DM]), hypertension (HTN), dyslipidemia (DLP), coronary artery disease, and chronic kidney disease), medications, causes of RML, presenting signs and symptoms, vital signs upon admission, laboratory values (such as CPK, creatinine, estimated glomerular filtration rate [eGFR], blood urea nitrogen [BUN], albumin, lactate dehydrogenase, uric acid, anion gap, phosphorus, potassium, calcium, and blood counts at various intervals), type of administered fluids, complications such as acute kidney injury (AKI) and acute liver failure(ALF), intensive care unit (ICU) admission, length of hospitalization, and mortality rate. RML was defined by a CPK level of at least 1000 IU/L, and AKI was defined as an increase in serum creatinine by at least 1.5 times the baseline.

Statistical analysis. The analysis employed IBM SPSS Statistics for Windows, version 28 (IBM Corp., Armonk, N.Y., USA). Categorical data were presented as frequency and percentage (%), and numerical data as median and interquartile range (IQR). The Mann-

Whiteny test was used to compare continuous variables, and the Fisher's exact test was utilized for categorical variables. All reported *p*-values were 2-tailed, with significance determined at a level below 0.05.

Results. Table 1 displays the baseline characteristics of the patients. A total of 58 patients were included. Over 3-quarters (84.5%) of our cohort were male, with a median age of 41 (IQR 27–60.5) years and a median BMI of 26.5 (IQR 23.6–29.5) kg/m^2. The most prevalent comorbidities included HTN (27.6%), DLP (25.9%) and DM (24.1%). Less than a quarter (17.3%) of the patients had neuropsychiatric diseases, including 3 cases of ischemic stroke and one case of cerebral palsy, epilepsy, peripheral neuropathy, Guillain-Barré syndrome, Alzheimer's disease, bipolar disorder, and depression. A small proportion (5.2%) of the patients had a previous episode of RML. The most frequently used medications were statins (22.4%) and recreational drugs (20.7%), mainly heroin and amphetamine.

Table 2 presents the causes of RML among our participants. Notably, these causes were determined by reviewing the EHR for the diagnoses provided by the treating physicians, then the principal investigator of this study meticulously examined all diagnoses to ensure accuracy. Medications caused almost half (44.8%) of RML cases, with statins being the most commonly implicated (22.4%), followed by recreational drugs (15.5%) and antipsychotics (6.9%). Other frequent causes of RML were strenuous exercise (29.3%), infections (10.3%), which mainly took the form of

Table 1 - Patients' demographics and baseline characteristics (N=58).

Factors	n	%
Age (years)	41 (27-60.5)*	
BMI (kg/m^2)	26.5 (23.6-29.5)*	
Gender		
Male	49	84.5%
Female	9	15.5%
Comorbidities		
Hypertension	16	27.6%
Dyslipidemia	15	25.9%
Diabetes mellitus	14	24.1%
Neurological diseases	7	12.1%
Coronary artery disease	6	10.3%
Hypothyroidism	6	10.3%
Chronic kidney disease	4	6.9%
Psychiatric diseases	3	5.2%
Previous episode of rhabdomyolysis	3	5.2%
Baseline medications		
Statins	13	22.4%
Recreational drugs**	12	20.7%
Antipsychotics	6	10.3%
Anti-epileptics	6	10.3%
Antidepressants	1	1.7%

*Median (interquartile range). **Heroin and amphetamine.
BMI: body mass index

Table 2 - Causes, complications, and outcomes of rhabdomyolysis (N=58).

Causes of rhabdomyolysis	n	%
Medication-induced	26	44.8%
Statins	13	22.4%
Recreational drugs	9	15.5%
Antipsychotics	4	6.9%
Strenuous exercise	17	29.3%
Infection	6	10.3%
Trauma	5	8.6%
Seizure	1	1.7%
Post-operative	1	1.7%
Hypernatremia/dehydration	1	1.7%
Unknown	1	1.7%
Complications of rhabdomyolysis		
Acute kidney injury	19	32.8%
ICU admission	10	17.2%
Acute liver failure	5	8.6%
Need for dialysis	3	5.2%
Compartment syndrome	1	1.7%
Outcomes of rhabdomyolysis		
Length of hospital stay	5 (3-10.3)	
Death	5	8.6%

ICU; intensive care unit

Table 3 - Patients' vital signs and presenting signs and symptom (N=58).

Factors	n	%
Vital signs on admission		
Systolic blood pressure	125 (110-141)	
Diastolic blood pressure	68.5 (61-77)	
Heart rate	87.5 (73-109.3)	
Respiratory rate	20 (19-23)	
Oxygen saturation	97.5 (96-98)	
Clinical features of rhabdomyolysis		
Myalgia	37	63.8%
Fatigue	22	37.9%
Altered level of consciousness	14	24.1%
Dark urine	10	17.2%
Focal weakness	9	15.5%
Gastrointestinal manifestations	7	12.1%
Fever	7	12.1%
Dizziness	5	8.6%
Electrocardiograph changes	20	34.5%
T Wave abnormality	5	8.6%
Premature ventricular complexes	3	5.2%
Left ventricular hypertrophy	3	5.2%
Sinus tachycardia	3	5.2%
First-degree AV block	2	3.45%
Prolonged Q-T	2	3.45%
Right bundle branch block	1	1.7%
Short P-R interval	1	1.7%

AV: atrioventricular

urinary tract infection and pneumonia, and trauma (8.6%), mainly motor vehicle accidents.

Table 3 shows the patients' vital signs and presenting signs and symptoms of RML. The most notable clinical features were myalgia, fatigue, and an altered level of consciousness, accounting for 63.8%, 37.9%, and 24.1%, respectively. Other less prevalent features were dark urine (17.2%), focal weakness (15.5%), fever (12.1%), and gastrointestinal symptoms (12.1%), mainly in the form of abdominal pain, nausea, and vomiting. In addition, over one-third (34.5%) of the patients had electrocardiographic (ECG) changes upon presentation, with nonspecific T-wave changes constituting the majority (8.6%) of the observed ECG abnormalities.

Table 4 shows important laboratory values at different time intervals. Upon admission, the median CPK was 6090 IU/L (IQR 1805–18962.8), and the median creatinine was 102.5 umol/l (IQR 69.8–191.5). All the patients received supportive care, including hospital admission of a median stay length of 5 days (IQR 3–10.3), electrolyte replacement, and fluid management, primarily using normal saline (93.1%).

Acute kidney injury occurred in 19 (32.8%) patients, 3 of whom required hemodialysis. Acute liver failure occurred in 5 (8.6%) patients, and one patient developed compartment syndrome (1.7%). Compared to the group without complications, patients with complications (defined as a composite of AKI, ALF, multiorgan failure, or mortality) exhibited a significantly lower eGFR (p<0.001) and higher levels of serum creatinine (p<0.001), BUN (p<0.001), anion gap (p=0.001), and uric acid (p=0.007) upon admission as shown in Table 5. However, the bivariate comparison showed no significant statistical difference in baseline characteristics or CPK levels among the groups. Notably, despite having similar serum albumin levels upon admission, the group with complications had significantly lower albumin levels during hospitalization (p=0.001) and upon discharge (p=0.006). Almost one-fifth (17.2%) of the patients required ICU admission, with a median length of ICU stay of 5 days (IQR 2.8–10.8). Among the 5 (8.6%) patients who succumbed, causes included 3 deaths due to septic shock, one due to ischemic stroke, and one due to decompensated heart failure.

Discussion. Rhabdomyolysis is a clinical syndrome that arises as a consequence of myocyte cellular membrane damage, hypoxia, energy depletion, and oxidative free radical generation, resulting in apoptosis and subsequent muscle cell necrosis that leads to the release of myocyte contents into the circulation.[2,3] In this article, we evaluated the clinical presentation, laboratory features, complications, and treatment outcomes of 58 Saudi patients with RML induced by different acquired causes.

The lack of a consensus on the definition of RML has led to inconsistencies among different reports.[3] In one systematic review that included 414 articles concerning RML, only one-third of the articles provided a definition for the condition.[5] The most commonly used definition is a CPK level >1000 IU/L or 5 times the upper limit of normal, followed by elevated CPK without a specific threshold, clinical symptoms, myoglobinuria, elevated serum myoglobin, ICD code-based, and muscle biopsy.[5] In this study, RML was defined as a CPK level of at least 1000 IU/L, aligning with the most frequently used definition in the literature. We believe that using this threshold combined with the relevant clinical features accurately diagnose RML.

The presentation of RML is highly heterogenous and nonspecific, with an unpredictable clinical course dependent on the underlying cause and medical condition.[8] Symptoms range from local manifestations like muscle pain, tenderness, and swelling to life-threatening systemic manifestations such as altered mentation, anuria, and cardiac arrest.[3] In this study,

Table 4 - Important longitudinal laboratory values.

Factors	Before Admission	Admission	Maximum	Discharge
CPK	99 (52.5 to 157.8)	6090 (1805 to 18962.8)	10218 (2700.8 to 29318)	692.5 (263.8 to 4908.3)
Creatinine	74 (67.3 to 107.5)	102.5 (69.8 to 191.5)	103.5 (70.8 to 231.3)	69 (59 to 98.3)
BUN	5.2 (3.8 to 7)	6.2 (3.9 to 10.9)	6.5 (4.3 to 14.5)	4.3 (2.8 to 6.9)
eGFR	95 (61 to 128)	68 (32.8 to 116)	70.5 (22.8 to 125.5)	114 (71 to 146)
Anion	15 (13 to 17)	16.5 (13.8 to 25)	17.5 (15.8 to 25.5)	13 (12 to 15)
Uric acid	342.5 (277 to 444)	413.5 (295.5 to 598.3)	413.5 (302.3 to 659.8)	289 (185.5 to 393)
Phosphorus	1.2 (1.1 to 1.4)	1.3 (1.1 to 1.7)	1.5 (1.2 to 1.9)	1.1 (1 to 1.3)
Potassium	4.2 (3.8 to 4.8)	4.3 (3.9 to 4.6)	4.6 (4.2 to 5.1)	3.9 (3.7 to 4.3)
Albumin	41 (39 to 46.5)	42.5 (38.8 to 47.3)	34 (27.8 to 39.3)	36.5 (32.3 to 40)

CPK: creatine phosphokinase, BUN: blood urea nitrogen, eGFR: estimated glomerular filtration rate

Table 5 - Comparison of the study cohort based on the development of complications (composite outcomes of death, acute kidney injury, acute liver failure, and/or multiorgan failure).

Characteristics	No complications		Complication		*P*-value
	n	%	n	%	
	37	63.8	21	36.2	
Age (years)	37 (27-51)		49 (30-67)		0.086
Body mass index (kg/m^2)	27 (23-28)		27 (24-30)		0.462
Gender					
Male	30	81.1%	19	90.5%	0.465
Female	7	18.9%	2	9.5%	
Hospital stay (days)	4 (3-6)		6 (3-14)		0.104
The most common comorbidities					
Hypertension	8	21.6%	8	38.1%	0.266
Dyslipidemia	8	21.6%	7	33.3%	0.363
Diabetes mellitus	9	24.3%	5	23.8%	1
Important laboratory values at different time intervals	Median (IQR)				
Creatinine before admission (umol/l)	71 (66-77)		111 (74-125)		0.008
Creatinine on admission (umol/l)	77 (68-104)		217 (125-506)		<0.001
Maximum creatinine (umol/l)	76 (68-104)		230 (132-505)		<0.001
Creatinine on discharge (umol/l)	63 (59-70)		98 (69-144)		0.001
BUN before admission (mmol/l)	4 (4-5)		7 (5-9)		0.001
BUN on admission (mmol/l)	5 (5-6)		11 (9-20)		<0.001
Maximum BUN (mmol/l)	5 (4-7)		14 (9-21)		<0.001
BUN on discharge (mmol/l)	4 (3-5)		7 (5-9)		0.002
eGFR before admission (ml/min/1.73m2)	107 (83-131)		61 (42-95)		0.008
eGFR on admission (ml/min/1.73m2)	99 (67-128)		33 (14-50)		<0.001
Lowest eGFR (ml/min/1.73m2)	101 (67-131)		23 (12-49)		<0.001
eGFR on discharge (ml/min/1.73m2)	133 (102-151)		76 (46-115)		0.006
CPK on admission (IU/L)	8033 (2221-20042)		4878 (1607-16180)		0.288
Maximum CPK (IU/L)	10440 (2830-37325)		9910 (2664-25244)		0.764
CPK on discharge (IU/L)	731 (302-5136)		480 (230-3220)		0.417
Uric acid on admission (umol/l)	362 (287-488)		518 (378-1064)		0.007
Maximum uic acid (umol/l)	390 (287-530)		572 (378-1077)		0.01
Uric acid on discharge (umol/l)	289 (187-376)		305 (186-408)		0.966
Anion gap on admission (mmol/l)	15 (13-18)		25 (16-29)		0.001
Maximum anion gap (mmol/l)	17 (15-19)		25 (17-29)		0.005
Anion gap on discharge (mmol/l)	14 (12-15)		13 (17-29)		0.197
Albumin on admission (g/l)	44 (40-46)		40 (36-52)		0.674
Lowest albumin (g/l)	36 (33-40)		28 (23-35)		0.001
Albumin on discharge (g/l)	39 (36-40)		34 (30-39)		0.006

BUN: blood urea nitrogen, eGFR: estimated glomerular filtration rate, CPK: Creatine phosphokinase

myalgia was the most common presenting complaint, consistent with existing literature, where it is consistently identified as the primary presenting complaint regardless of age or underlying cause, although most large studies did not extensively report presenting manifestations.[9-12]

Rhabdomyolysis is often a secondary manifestation of an underlying etiology. The underlying etiologies can be categorized broadly into genetic and acquired causes.[1,2] The genetic causes of RML include but are not limited to McArdle's disease, Duchenne's muscular dystrophy, short-chain and very-long-chain acyl-CoA dehydrogenase deficiency, and carnitine metabolism disorders.[13] The congenital RML is beyond the scope of the current study as we excluded any patient with a genetic cause of myopathy. In this study, medications, particularly statins and illicit drugs, were the leading causes of RML cases. This is consistent with the literature as, in adults, the most common cause of RML in developed countries is the use of prescribed medications, alcohol, or recreational drugs.[14]

In Saudi Arabia, dyslipidemia prevalence can be as high as 44%, leading to frequent statin prescriptions.[18] The rate of RML among statin users is up to 3.7 per 10,000 persons per year, rising to 22.5 when combined with other myotoxic medications such as fibrates.[17] This risk is higher in those older than 65 years and

with preexisting kidney impairment.[4] Confirming this, our study found that patients with preexisting kidney impairment, depicted by high baseline creatinine, BUN, and low eGFR, had a significantly higher risk of RML complications. Our findings suggest informing statin users, especially those at risk, about RML possibilities. Encouraging them to report muscle pain and fatigue to their physicians could lead to a timely diagnosis, preventing serious complications.

Recreational drugs, such as heroin, cocaine, amphetamines, cannabinoids, and ecstasy, are common precipitants to RML worldwide. They can trigger RML through various mechanisms, including direct myotoxicity, vasoconstriction, ischemia, prolonged immobilization, or a combination of these mechanisms.[19,20] Despite the low prevalence of recreational drug use in Saudi Arabia (7%-8% of the population), this study found that 15.5% of RML cases were attributed to such drugs, particularly heroin and amphetamine.[21] Unfortunately, RML induced by recreational drugs has a poor prognosis. A study of 475 patients admitted with RML found that almost half of the cases were due to recreational drug use; compared to the other patients, most of the patients with drug-induced RML had severe AKI, necessitating dialysis, and their mortality rate was higher, ranging from 19% to 59%.[22]

In this study, strenuous exercises accounted for 29.3% of RML cases, a higher percentage than reported in several other studies.[23,24] Notably, KAMC is a military hospital, possibly explaining the elevated exercise-induced RML cases. To take a related example, in the United States, exercise-induced RML reached 38.6 per 100,000 in 2021, particularly prevalent among military recruits engaged in strenuous outdoor activities.[25] Outdoor exercises like running and cycling pose a higher risk of RML compared to indoor activities like weight lifting.[26] Also, the high average temperature in Saudi Arabia, reaching 54°C (130°F) in summer, may contribute to the elevated cases.[27] Fortunately, exercise-induced RML tends to be relatively benign. A study of 430 RML patients found only 4.9% (n=20) attributed to exertion, with a mild course, including 5 cases of mild AKI and no deaths.[28]

In our study, 32.8% of patients were diagnosed with AKI, with 5.2% requiring dialysis. It is known that AKI is considered the most common complication of RML, with an incidence rate ranging from 10% to 55%.[29] The mechanism of AKI in RML involves muscle destruction, causing fluid and enzyme leakage, leading to intracellular volume depletion and activation of the renin-angiotensin-aldosterone system.[30,31] This study conducted a bivariate comparison of patients with and without complications, revealing significantly higher blood levels of creatinine, BUN, uric acid, and anion gap in patients with complications. These values may have prognostic significance. A study that evaluated 126 patients with different causes of RML identified hypoalbuminemia, metabolic acidosis, and decreased prothrombin time as poor prognostic factors in RML.[32] This is consistent with our findings since patients with complications had significantly lower albumin levels during their admission (p=0.001) and upon discharge (p=0.006) than patients without complications. However, CPK levels on admission did not show a statistical difference in patients with complications, possibly due to the study's limited cohort of critically ill individuals. Creatine phosphokinase's lack of specificity to skeletal muscles may be a factor, as concomitant conditions in critically ill patients can elevate CPK levels, complicating its predictive value for AKI.[33]

Based on previous reports, AKI is a poor prognostic factor for RML, especially when other organ damage, such as liver failure, is diagnosed simultaneously.[30] Unlike in the literature, only a few (8.6%) of our patients had ALF; the rate of ALF can reach 25% in RML, owing to secondary proteases released due to muscle injury.[1,34]

In our sample, all patients were hospitalized, with 17.2% (n=10) requiring ICU treatment. The mortality rate was 8.6%, with 3 deaths due to septic shock, one to ischemic stroke, and one to decompensated heart failure. The rate of ICU admission may be slightly elevated owing to the variations in RML causes; however, it aligns with findings in previous studies. One study of 400 patients with diverse RML causes, mainly from recreational drug abuse and infections, reported a 12% ICU admission rate and 5.3% mortality.[12] Another study showed a mortality rate of 12% among 106 patients with RML induced by factors like recreational drug/alcohol use, trauma, compression, and shock.[7] Mortality varies based on underlying causes and overall patient health; for example, ICU-admitted patients with AKI have a 59% mortality rate compared to 22% in those without AKI.[32] However, comparing the results of different studies is challenging due to diverse causes, age groups, and limited reporting of ICU admission rates in most studies. Unlike ours, many studies focused on specific populations, such as statin users, trauma patients, or military recruits.

This study possesses both strengths and weaknesses. The study furnishes comprehensive data on clinical and laboratory features, causes, complications, and treatment outcomes, aiding clinicians in recognizing

the varied presentation of RML. The sample, while diverse in causes, represents a dual aspect of strength and weakness.

Study limitations. Our study limitations include a relatively limited sample size and retrospective design, hindering robust conclusions. The descriptive and observational nature restricts statistical analysis. In addition, the study generalizability is constrained by its a single-center design and the military hospital setting.

In conclusion, this study offers a thorough understanding of clinical and laboratory features, underlying causes, complications, and treatment outcomes of RML, contributing to raising awareness among clinicians and, hopefully, reducing the disease burden. However, further study with a larger sample size is warranted to gain a deeper understanding of the diverse disease behaviors associated with the different causes of RML. This would enhance our knowledge and enable more rapid and effective management strategies for RML.

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