Original article

Research on clinical, biological characteristics, and treatment of hyperkalemia in acute kidney injury patients

Tran Thuy Quynh[1], Vo Tam[2], Hoang Trong Hanh[1], Dam Trung Nghia[2], Hoang Anh Tien[2*]
[1]Hue Centre Hospital
[2]Hue University of Medicine and Pharmacy

***Corresponding Author:** Hoang Anh Tien, email: hatien@hueuni.edu.vn
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Abstract

Purpose: This study investigated the clinical and paraclinical characteristics and severity of hyperkalemia in patients with acute kidney injury (AKI) treated in the Intensive Care Unit of Hue Central Hospital, and evaluated treatment outcomes and associated factors.

Methods: A total of 121 AKI patients treated from March 2022 to June 2023 were included. Data on medical history, clinical features, laboratory findings, and hyperkalemia treatment outcomes were collected and analyzed.

Results: Hypertension was the most common comorbidity (38.8%), followed by pulmonary disease (34.7%) and diabetes (20.7%). AKI was most often detected during hospitalization (62.8%). The leading cause was sepsis/infection (90.9%), followed by nephrotoxic drugs (38.0%). Common clinical manifestations included dyspnea or tachypnea (86.0%), shock or cardiac arrest (76.0%), edema (60.3%), and fatigue (57.0%). Most patients had normal consciousness (66.9%), while 13.2% were comatose. Stage 3 AKI predominated (54.5%), with 60.3% having urine output < 0.5 ml/kg/hour. Electrocardiographic abnormalities included tachycardia or bradycardia (79.3%), ST segment depression (23.1%), flattened P waves (14.9%), and peaked T waves (13.2%). Hyperkalemia (serum potassium ≥ 5.5 mmol/L) occurred in 52.1% of patients, with severe hyperkalemia (≥ 6.5 mmol/L) in 10.7%. Mild hyperkalemia was most common (76.0%), while severe cases accounted for 21.5%. Calcium chloride was the most frequently used treatment (79.4%), followed by diuretics (63.5%), sodium bicarbonate (58.7%), and insulin with glucose infusion (57.1%). Continuous renal replacement therapy (CRRT) was applied in 19.0% of patients. Potassium levels normalized to < 5.5 mmol/L in 81.0% of patients within 6 hours and 84.1% after 6 hours. Serum potassium levels improved significantly after medical therapy or CRRT (P < 0.001). No significant associations were found between treatment outcomes and age, sex, BMI, admission characteristics, timing of detection, or hematological parameters.

Conclusions: AKI patients in the ICU commonly presented with dyspnea and shock/cardiac arrest. Hyperkalemia was frequent (52.1%), including 10.7% severe cases, but potassium levels improved significantly with appropriate treatment.

Keywords: *hyperkalemia; acute kidney injury; complication.*

1. INTRODUCTION

Acute Kidney Injury (AKI) is a condition characterized by an imbalance in fluid, electrolyte, and acid-base status, leading to a decreased glomerular filtration rate. It is a common pathological condition in emergency critical care settings, often occurring within the context of multiple organ dysfunction syndrome (MODS), and is an independent risk factor for prolonged hospital stays, mechanical ventilation duration, and increased mortality rates [1]. The mortality rate of patients with AKI depends on the cause and severity of the injury, with up to 25 - 70% of critically ill patients being affected in intensive care units [2].

Hyperkalemia is commonly encountered in patients with AKI. Managing hyperkalemia is a critical emergency intervention because of the risk of cardiac arrhythmias and cardiac arrest leading to death. Several studies have shown that hyperkalemia is associated with poor patient prognosis [3]. In our clinical experience at the Intensive Care Unit of Hue Central Hospital, we observed many AKI patients with hyperkalemia requiring treatment, with successful outcomes in most cases. However, no specific studies have addressed this issue in our department. Therefore, we conducted a study titled "Clinical, Biological Characteristics, and Treatment of Hyperkalemia in Patients with Acute Kidney Injury in the Intensive Care Unit of Hue Central Hospital" with the following objectives:

1. To study the clinical and biological

characteristics and the degree of hyperkalemia in AKI patients at the Intensive Care Unit of Hue Central Hospital.

2. Evaluation of treatment outcomes for hyperkalemia.

2. SUBJECTS AND METHODS

2.1. Study Subjects

This study included 121 patients with acute kidney injury (AKI) treated at the Intensive Care Unit of Hue Central Hospital from March 2022 to June 2023.

2. Study Methodology:

2.1. Study Design:

This was a cross-sectional descriptive study with follow-up.

2.2. Procedure:

- Data Collection: Medical history, including underlying diseases, characteristics of the time to AKI detection, nephrotoxic drugs.

- Causes of AKI: Clinical features of AKI injury

- Collection of Laboratory Data: Electrocardiography (ECG).

- Creatinine levels: Continuous monitoring of electrolyte levels before and 6 h after the time of detection.

- Data Processing: Statistical methods were employed using SPSS 22.0 software.

Comparisons were made using the χ2 test, correlation analysis, odds ratio calculation, and Student's t-test.

2.3. Evaluation Criteria:

2.3.1. Definitive Diagnosis of Acute Kidney Injury [4]

According to the KDIGO (Kidney Disease: Improving Global Outcomes), AKI can be diagnosed if any one of the following is present:

- Increase in the serum creatinine value of ≥ 0.3 mg/dL (26.52 micromol/L) in 48 hours
- Increase in serum creatinine of ≥ 1.5 times baseline within the prior 7 days
- Urine volume < 0.5 mL/kg/hour for 6 hours.

2.3.2. Diagnosis of Acute Kidney Injury Stage

Diagnosis of Acute Kidney Injury Stage [4]

Stage	Serum creatinine	Amount of urine produced
1	1.5 - 1.9 times the initial value; OR ≥ 0.3 mg/dL (26.52 micromoles/L)	< 0.5 mL/kg/h for 6 - 12 h
2	2 - 2.9 times the initial value	< 0.5 mL/kg/hour for ≥ 12 h
3	≥ 3 times the initial value; OR ≥ 4.0 mg/dL (353.60 micromoles/L); OR if renal replacement therapy is initiated; OR in patients < 18 years, decrease in eGFR to < 35 ml/min per 1.73 m^2	< 0.3 mL/kg/h for ≥ 24 h OR anuria for ≥ 12 h

2.3.3. Blood Potassium Elevation

Classification of Potassium concentration Levels (KDIGO 2020) [5]:

		Potassium concentration (mmol/l) (*5.0 or upper limit of normal range)		
		5.0* - 6.0	6.1 - 6.5	> 6.5
ECG changes	+	Moderate	Severe	Severe
	-	Mild	Moderate	

2.3.4. Indication for Continuous Renal Replacement Therapy (CRRT): *KDIGO 2020 [5]*

3. RESULTS

Table 1. Characteristics of the Study Population

Characteristics	Values
Average Age	64.8 ± 15.8
Male Ratio	77.7% (n = 94)
Female Ratio	22.3% (n = 27)
BMI (kg/m2)	21.4 ± 3.0

The average age in the study group was 64.8 ± 15.8 years. The oldest participant was 91 years old, whereas the youngest was 19 years old. The 60 – 79 years age group accounted for the highest proportion (48.8%). Among them, males constituted the majority (77.7%). Additionally, the average BMI in the study group was 21.4 ± 3.0 kg/m^2. The BMI

range from 18.5 - 22.9 accounts for the highest proportion (52.1%).

Table 2. Underlying Medical History of the Study Population

Medical History	n	%
Chronic Kidney Disease	15	12.4
Diabetes Mellitus	25	20.7
Hypertension	47	38.8
Cancer	15	12.4
Liver Cirrhosis	6	5,0
Coronary Artery Disease	15	12,4
Lung Disease	42	34.7
Cerebrovascular Accident	11	9.1
Heart Failure	21	17.4
Cardiac Arrhythmia	4	3.3
At least 1 underlying medical condition	104	86.0

Hypertension accounted for the highest proportion of medical history (38.8%), followed by lung disease (34.7%), diabetes mellitus (20.7%) and heart failure (17.4%).

Table 3. Characteristics of the Time of Acute Kidney Injury Detection

Time of Detection	n	%
At hospital admission	45	37.2
During Hospitalization	76	62.8

The most common time of acute kidney injury detection is during hospitalization (62.8%), followed by Hospital admission (37.2%).

Table 4. Characteristics of the Causes of Acute Kidney Injury in the Study Population

Cause	n	%
Heart Failure	32	26.4
Nephrotoxic Drugs	46	38.0
Sepsis/Bacterial Infection	110	90.9
Volume Depletion	20	16.5
Interstitial Kidney Disease	14	11.6
Toxicity	2	1.7
Urinary Obstruction	2	1.7
Liver Cirrhosis	4	3.3

The most common cause of kidney injury was sepsis/bacterial infection (90.9%). Nephrotoxic drugs were the second most common cause of death (38.0%).

Table 5. Clinical Characteristics of Acute Kidney Injury in the Study Population

Clinical Symptoms	n	%
Edema	73	60.3
Fatigue	69	57.0
Nausea or Vomiting	39	32.2
Muscle Weakness or Numbness	10	8.3
Palpitations or Irregular Heartbeat	2	1.7
Chest Pain	22	18.2
Abdominal Pain or Diarrhea	41	33.9
Shortness of Breath or Rapid Breathing	104	86.0
Shock or Cardiac Arrest	92	76.0

The most common symptom was shortness of breath or rapid breathing (86.0%). Shock or cardiac arrest (76.0%), edema (60.3%), and fatigue (57.0%) were also common symptoms.

Table 6. Classification of Acute Kidney Injury Stages in the Study Population

Stage	n	%
Stage 1	17	14.0
Stage 2	38	31.4
Stage 3	66	54.5

Stage 3 of acute kidney injury accounted for the highest proportion (54.5%). This was followed by stage 2 (31.4%).

Table 7. Characteristics of Urine Output in the Study Population

Urine Output	n	%
< 0.5 ml/kg/hour	73	60.3
≥ 0.5 ml/kg/hour	48	39.7
Median (interquartile range)	0,3 (0.1 - 0.9)	

The majority of urine output was < 0.5 ml/kg/hour (60.3%).

Table 8. Characteristics of Electrocardiogram Changes in the Study Population

Electrocardiogram Changes	n	%
Fast/Slow Heart Rate	96	79.3

Flattened P Wave	18	14.9
Prolonged PR Interval	0	0.0
Prolonged QRS Duration	12	9.9
ST Segment Depression	28	23.1
Tall, Symmetrical T Wave	16	13.2
Junctional Rhythm	4	3.3
Block AV	10	8.3
Sinus Bradycardia	3	2.5
Atrial fibrillation	11	9.1
Ventricular fibrillation	1	0.8
Any Change Detected	113	93.4

The most common electrocardiogram manifestation was heart rate variation (79.3%). Subsequently, ST segment depression (23.1%), flattened P waves (14.9%), and tall, symmetrical T waves (13.2%) were frequently observed.

Table 9. Characteristics of Blood Potassium Elevation Levels in the Study Population

Hyperkalemia Level	n	%
Mild	92	76.0
Moderate	3	2.5
Severe	26	21.5
Mean ± SD	5.7 ± 0.7	

Mild hyperkalemia accounted for the highest proportion (76.0%) of cases. Severe hyperkalemia accounted for 21.5% of the cases.

Table 10. Characteristics of Hyperkalemia Treatment Methods in the Study Population

Treatment Method	n	%
Discontinuation of Nephrotoxic Drugs	6	9.5
Calcium Chloride IV	50	79.4
Insulin + Glucose	36	57.1
Sodium Bicarbonate	37	58.7
Diuretics	40	63.5
Inhaled Salbutamol	21	33.3
Hemodialysis	4	6.3
Continuous Renal Replacement Therapy (CRRT)	12	19.0

Calcium Chloride IV (79.4%) is the most commonly used treatment method. This was followed by diuretics (63.5%), sodium bicarbonate (58.7%), and insulin plus glucose infusion (57.1%). CRRT was used in 19.0% of cases.

Table 11. Results of Hyperkalemia Treatment in the Study Population

Treatment Outcome / Time Point	Before Treatment (a)		Before 6 hours (b)		After 6 hours (c)	
	n	%	n	%	n	%
Improvement	0	0.0	51	81.0	53	84.1
No Improvement	63	100.0	12	19.0	10	15.9
Average Blood Potassium	6.1 ± 0.7		4.8 ± 0.8		4.5 ± 0.9	
p	-		p(a&b) < 0.001		p(a&c) < 0.001	
Degree of Blood Potassium Reduction (mmol/L)	0		1.3 ± 0.8		1.6 ± 1.04	

There was a significant decrease in the blood potassium concentration after treatment at both time points before and after 6 h (p <0.001).

Table 12. Relationship between Blood Potassium Concentration and Treatment Methods

Treatment Method / Time Point	n	Before Treatment (a)	< 6 hours (b)	> 6 hours (c)	p	
					(a)&(b)	(a)&(c)
CaCl IV	50	6.2 ± 0.7	4.8 ± 0.8	4.5 ± 0.8	< 0.001	< 0.001
Ins +Glu	36	6.2 ± 0.7	4.9 ± 0.9	4.6 ± 0.9	< 0.001	< 0.001
HCO3-	37	6.2 ± 0.8	4.8 ± 0.8	4.4 ± 0.8	< 0.001	< 0.001
Diuretics	40	6.1 ± 0.6	4.8 ± 0.7	4.6 ± 0.9	< 0.001	< 0.001
Beta Agonists	21	6.2 ± 0.7	4.8 ± 0.8	4.5 ± 0.7	< 0.001	< 0.001
Hemodialysis/CRRT	16	6.0 ± 0.4	4.6 ± 0.6	4.3 ± 0.7	< 0.001	< 0.001

At both time points before and after 6 h, there was a significant improvement in the blood potassium concentration across all treatment methods ($p < 0.001$).

4. DISCUSSION

4.1. Clinical, Biological Characteristics, and Blood Potassium Level in Patients with Acute Kidney Injury (AKI) at the Intensive Care Unit of Hue Central Hospital

Risk factors for AKI in hospitalized patients include chronic kidney disease, cardiovascular disease, heart failure, liver disease, pre-existing AKI, anemia, and neurological disorders [6]. Recent evidence suggests that even mild hyperkalemia can lead to adverse outcomes such as hospitalization and mortality. Moreover, it may prevent patients from receiving optimal internal medical therapy for heart failure by reducing the indications for RAASi treatment.

The most common time for detecting AKI was during hospitalization (62.8%), which is consistent with the study by Pham Thi Dieu Huyen, where the detection rate at hospital admission was 39.3% and during hospitalization was 60.7% [7]. Regarding the causes of AKI, most studies agree on common causes such as sepsis, heart failure, and hypovolemic shock [8]. According to Mishra, the sensitive risk factors for AKI include advanced age, hypertension, cardiovascular diseases, pre-existing chronic kidney disease, burns, cardiac surgery, muscle wasting, volume depletion, fluid overload, nephrotoxic drugs and agents, sepsis, chronic heart disease, prolonged shock, and vasopressor use [9].

Our study results showed that the most common symptoms were dyspnea and rapid breathing (86.0%). This was followed by shock or cardiac arrest (76.0%), edema (60.3%), and fatigue (57.0%). Most of the patients (66.9%) had normal consciousness. Severe coma accounted for 13.2% of the cases. In contrast, a study by Le Thi Diem Tuyet found that 86 of 160 patients had significant edema (53.8%) [10].

Our results also revealed that stage 3 AKI accounted for the highest proportion (54.5%), followed by stage 2 (31.4%). Stage 1 accounted for 14.0% of the cases. In contrast, the results of Ha Ngoc Diem showed that stage 1 AKI accounted for the majority (46.5%), stage 2 was 33.3%, and stage 3 was 20.2% [11]. This difference may be due to the study population being patients with mild disease progression in clinical departments.

The most common finding on electrocardiography (ECG) was arrhythmia (79.3%). This was followed by ST segment depression (23.1%), flattened P wave (14.9%), and tall peaked T wave (13.2%). An increased potassium ion concentration affects the action potential of the heart. As the potassium concentration continues to rise, the conduction velocity decreases (leading to prolonged PR and QRS complexes) and refractoriness increases, promoting cardiac conduction block. Therefore, hyperkalemia can manifest as any ECG abnormality: changes in P, QRS, ST, or T waves; conduction block changes; new conduction block; heart block; ventricular fibrillation; or ventricular tachycardia. However, the sensitivity and specificity of ECG changes for hyperkalemia (and death from hyperkalemia-induced arrhythmias) are low, and many cases report normal or nearly normal ECGs in patients with severe hyperkalemia [12].

Our study results showed that mild hyperkalemia accounted for the highest proportion (76.0%). The proportion of patients with severe hyperkalemia was 21.5%.

4.2. Evaluation of the Results of Hyperkalemia Treatment

The goal of managing acute hyperkalemia is to prevent or minimize physiological effects on the heart to reduce the risk of immediate arrhythmias. Our study results showed that 63 patients had hyperkalemia with potassium levels ≥ 5.5 mmol/L or higher. These patients were treated for hyperkalemia. Among these, calcium chloride was the most common (79.4%). This was followed by diuresis (63.5%), sodium bicarbonate (58.7%), and insulin plus glucose infusion (57.1%). CRRT was used in 19.0% of the cases. Four patients underwent intermittent renal replacement therapy (IRRT). The results showed that the rates of improvement in potassium levels to <5.5 mmol/L before 6 h were 81.0% and after 6 hours was 84.1%, respectively. Additionally, there was a significant improvement in potassium levels both before and after 6 hours of hyperkalemia treatment. The group that received CRRT had the highest treatment improvement rate, both before and after 6 h. This was followed by diuresis and beta agonist therapy. Therefore, in most cases of hyperkalemia, if patients do not respond to internal medical treatment, CRRT shows a good response.

Salbutamol (e.g., albuterol) is effective in lowering potassium levels, with no difference between inhalation and intravenous administration in terms of efficacy [13, 14], although the efficacy may seem different. Although insulin dextrose has never been compared to placebo in the treatment of hyperkalemia, it has shown similar effects on serum potassium as salbutamol in a study of 20

patients [13], but with insulin lowering serum potassium faster (i.e., 15 min vs. 30 min). Notably, the combination of both treatment methods further reduced serum potassium levels compared with the individual treatment methods. In our study, hyperkalemia management frequently involved combination therapy. The majority of patients (> 70%) received two or more concurrent treatment methods, most commonly calcium salts combined with insulin–glucose infusion, diuretics, sodium bicarbonate, or beta-agonists. Patients with severe or refractory hyperkalemia often received combined medical therapy followed by CRRT.

In a recent randomized controlled trial, sodium bicarbonate infusion (4.2%) was used in severely ill patients with severe metabolic acidosis (pH < 7.2) [1]. There was no difference in the primary outcome (death from any cause at day 28 or organ failure at day 7), but the sodium bicarbonate group had significantly lower potassium levels than the control group.

Regarding furosemide diuresis, except in patients with symptomatic fluid overload, diuretics should not be considered as a treatment for hyperkalemia. A major drawback of diuretics is unpredictable sodium excretion and diuresis, especially in patients with AKI or heart failure. These patients may resist the diuretic and natriuretic effects of diuretics, making it a poor strategy for controlling severe hyperkalemia.

CRRT is the most commonly used method in intensive care units (ICUs). Both conventional and continuous renal replacement therapies can cause secondary hypokalemia in patients. Both hyperkalemia and rapid hypokalemia are associated with cardiac events and sudden death in patients with end-stage renal disease.

The adverse effects of hyperkalemia on the cardiac conduction system can be fatal. Stabilizing the membrane with calcium salts and shifting potassium, such as insulin and salbutamol, is the cornerstone of managing acute hyperkalemia. However, only dialysis, potassium-binding agents, and novel diuretics can remove K from the body.

5. CONCLUSION

The clinical symptoms of acute kidney injury (AKI) in the Intensive Care Unit of Hue Central Hospital are diverse and mainly present as dyspnea, shock, or cardiac arrest. Among them, the proportion of patients with potassium levels ≥ 5.5 mmol/L and 52.1% had severe hyperkalemia accounting for 10.7%. However, potassium levels showed statistically significant improvement with Internal Medicine methods, dialysis, and CRRT.

6. RECOMMENDATIONS

It is essential to note the risk of AKI in patients with septicemia/bacteraemia because the incidence is very high (90.9%). Additionally, attention should be paid to the detection of AKI in patients with symptoms of dyspnea, rapid breathing, shock or cardiac arrest, and edema. Treatment with beta-agonists and renal replacement therapy has shown better outcomes than other methods in managing hyperkalemia.

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