Serum potassium trajectory during AKI and mortality risk

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Abstract

Background: Kidneys play a primary role in potassium homeostasis. The association between potassium (sK^+) level and mortality or the need for kidney replacement therapy (KRT) during acute kidney injury (AKI) has not been adequately explored.

Methods: In this prospective cohort study, AKI patients admitted to the Hospital Civil de Guadalajara were enrolled from August 2017 to June 2021 with AKI. We divided patients into 8 groups based on the serum potassium level trajectories up to ten days following hospitalization, (1) normokalemia (normoK), defined as sK^+ values between 3.5 and 5.5 mEq/L; (2) corrected hyperkalemia (hyperK), $sK^+ > 5.5$ mEq/L on hospital admission and decreased to normoK; (3) corrected hypokalemia (hypoK), $sK^+ < 3.5$ mEq/L on hospital admission and increased to normoK; (4) fluctuating potassium, sK^+ increased / decreased in and out of normoK parameters; (5) uncorrected hypoK, $sK^+ < 3.5$ mEq/L; (6) normoK to hypoK, sK^+ that were normal on hospital admission and decreased to hypoK and never went back to normal; (7) normoK to hyperK, sK^+ that were normal on hospital admission and increased to hyperK and never went back to normal; (8) uncorrected hyperK, $sK^+ > 5.5$ mEq/L. We assessed the association of serum potassium trajectories with mortality and the need for KRT (secondary objective).

Results: A total of 311 AKI patients were included. The mean age was 52.6 years, and 182 (58.6%) were male. AKI stage 3 was present in 199 (63.9%). KRT started in 112 (36%) patients, and 66 (21.2%) died. After adjusting for confounders, 10-day hospital mortality was significantly higher in group 7 and 8 (OR, 1.37 and 1.63, $p = < 0.05$, for both, respectively), and KRT initiation was higher only in group 8 (OR 1.40, $p = < 0.05$) compared with group 1. Mortality in different subgroups of patients in group 8 did not change the primary results.

Conclusion: In our prospective cohort, most patients with AKI had alterations in sK^+ . NormoK to hyperK and Uncorrected hyperK were associated with death, while only uncorrected hyperK was correlated with the need for KRT.

Background

Acute kidney injury (AKI) is a complex syndrome associated with substantial morbidity and mortality (1, 2). These complications have been attributed, in part, to the alterations of the internal environment that are generated when kidney function decreases (3), limiting the capacity to excrete waste products. Approximately 90% of potassium is excreted via the kidneys, and these organs have a remarkable capacity to increase potassium excretion in the face of serum potassium (sK^+) excess (4). It is not surprising when kidney function decreases the odds of hyperkalemia (hyperK) are doubled (5). Excess sK^+ levels during AKI are one of the most common electrolyte abnormalities (6,7). The prevalence of hyperK in the intensive care unit was 3.4% with no AKI, 8.8% in AKI stage 1, 17% in AKI stage 2, and 32.2% in AKI stage 3 (8). When its levels increase, it is a feared complication (9) and is associated with poor outcomes in many different settings, including critical ill patients (10, 11), and it has been one of the

classic indications to start kidney replacement therapy (KRT) (12). Hypokalemia (hypoK), on the other hand, is also observed in patients with AKI, such as in cases of acute diarrhea (13); infections, such as leptospirosis (14); or diuretic use (15). In the acute setting, the risk of mortality associated with hypoK may be greater than with hyperK, which is mainly related to cardiac rhythm abnormalities (16). The Kidney Disease Improving Global Outcomes (KDIGO) Group Consensus for Dyskalemias in Kidney Diseases has emphasized the importance of research and understanding the burden of dyskalemias (16). This study tries to shorten this gap and investigates the association between the trajectory of sK^+ during hospitalization among patients with AKI and their outcomes. We hypothesize that sK^+ fluctuations, especially hyperK, are related to a higher probability of initiation of KRT and death.

Material And Methods

Study Design and Patient Population

A prospective cohort study was conducted at the Hospital Civil de Guadalajara Fray Antonio Alcalde, Mexico between August 2017 and June 2021; this is a tertiary referral academic center with 964 beds. All considered patients were under the care of a primary medical or surgical team. We only included those AKI patients when a nephrology consultation was requested by the attending physician. Attending nephrologists ran daily rounds and were available 24 h/day. Patients were evaluated and followed for the first 10 days after AKI diagnosis; we chose a 10-day follow-up because most AKI patients started KRT during this time period (12). AKI was diagnosed by the serum creatinine (sCr) KDIGO criteria (12). Patients who had available admission sK^+ and at least three sK^+ measurements during hospitalization, and with AKI diagnosis were included. The exclusion criteria were chronic kidney disease (CKD) stage 5 (defined as an estimated glomerular filtration rate of < 15 ml/min/1.73 m², using the 4-variable Modification of Diet in Renal Disease Study equation (MDRD-4) (12), chronic dialysis, < 48 hours of hospital stay, transplant patients, pregnant and missing data (unable to complete the analysis). The study was approved by Hospital Civil de Guadalajara Fray Antonio Alcalde Institutional Review Board (HCG/CEI-0550/15) and was conducted in adherence with the Declaration of Helsinki. Informed consent was obtained from all the subjects. The protocol followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (17).

Data Collection

Clinical characteristics, demographic information, and laboratory data were collected prospectively using automated retrieval from the institutional electronic medical record system. The main predictor of interest was the in-hospital sK^+ trajectory. In-hospital sK^+ trajectory was created based on sK^+ values during the hospital stay. sK^+ values were not available every single day because they were not always measured daily. For those who had more than one sK^+ measurement on the same calendar day, the mean sK^+ level was calculated to represent the sK^+ value for the index day. Demographic and clinical variables were collected as age, diabetes, hypertension, hypothyroidism, CKD grade, smoking, cerebrovascular disease, and ischemic heart disease; baseline serum creatinine level was defined as the most recent value within a

year before admission; contributing factors of AKI such as sepsis (Sepsis-3 criteria) (18), clinically hypovolemia, cardiorenal syndrome (19), nephrotoxic drugs and shock; prespecify biochemical data such as hemoglobin, platelets, leukocytes, glucose, urea, creatinine, sodium, potassium, chloride, phosphate, calcium, arterial pH, PCO₂, PO₂, bicarbonate and lactate levels. Indications for KRT were fluid overload resistant to diuretics, severe hyperkalemia, severe metabolic acidosis, and uremic manifestations, including encephalopathy, pericarditis, and convulsion (12, 20, 21).

sK⁺ trajectories

We focus on the main references for hyperK, defined as a sK⁺ concentration ≥ 5.5 mmol/l (22) and hypoK, defined as a sK⁺ concentration less than 3.5 mmol/l (5) and from these definitions, we choose other range groups. Group-based sK⁺ trajectory modeling considers the patterns of change for measures across multiple time points and identifies distinctive trajectories as shown in Fig. 1, sK⁺ trajectories were categorized into eight main trajectories: (Group 1) normokalemia (normoK), defined as sK⁺ values between 3.5 and 5.5 mEq/L; (Group 2) corrected hyperK, sK⁺ > 5.5 mEq/L on hospital admission and decreased to normoK; (Group 3) corrected hypoK, sK⁺ < 3.5 mEq/L on hospital admission and increased to normoK; (Group 4) fluctuating potassium, sK⁺ increased / decreased in and out of normoK parameters; (Group 5) uncorrected hypoK, sK⁺ < 3.5 mEq/L; (Group 6) normoK to hypoK, sK⁺ that were normal on hospital admission and decreased to hypoK and never went back to normal; (Group 7) normoK to hyperK, sK⁺ that were normal on hospital admission and increased to hyperK and never went back to normal; (Group 8) uncorrected hyperK, sK⁺ > 5.5 mEq/L.

Study outcomes

The primary outcome was to determine in-hospital mortality within 10 days of admission by sK⁺ trajectories. As secondary outcome we considered KRT start by sK⁺ trajectories

Statistical analysis

Continuous variables were summarized as mean $\pm$ SD unless otherwise specified. Categorical variables were summarized as numbers with percentages. Survival and KRT start after hospital admission were estimated using the Kaplan–Meier plot and compared using the log-rank test. Patients were followed until death or 10-days after hospital admission. Multivariable analysis was performed to assess the independent association between in-hospital sK⁺ trajectories and 10-days mortality and KRT start, using Group 1 normoK as the reference group. Model 1 was unadjusted, and in model 2 we adjusted for age, sex, gender, diabetes mellitus, hypertension, smoking, hypothyroidism, CKD, ischemic cardiopathy, cerebrovascular disease, sepsis, hypovolemia, cardiorenal syndrome, nephrotoxics used, shock, and AKI Stage. We performed a stratified subgroup analysis by age (< 65 or ≥ 65 years), gender, diabetes mellitus, hypertension, shock, sepsis, CKD, AKI KDIGO 3, and KRT. A two-tailed P value of < 0.05 was considered statistically significant. Statistics output was generated by a software package (R Studio 1.3.1093).

Results

Baseline characteristics

Between August 2017 and June 2021, a total of 527 patients received nephrology consultation for AKI in ICU. We excluded 41 (7.7%) patients with CKD stage 5 who were on dialysis, 89 (16.8%) with a length of hospital stay < 48 hours, 71 (13.4%) with missing admission or hospital sK^+ levels, and 15 (2.8%) patients due to a lack of data, which led to 311 patients in the final analysis (Fig. 2). We found 60.8% of enrolled patients with dyskalemia. The clinical characteristics of patients based on in-hospital sK^+ trajectories are shown in Table 1. The mean age of the patients was 52 ± 17 years, and 182 (58.6%) were male. One hundred and five (33.7%) had diabetes, and 22 (7.0%) had hypothyroidism. AKI stage 3 was present in 199 (63.9%) patients, and the main contributors to AKI included sepsis (45.9%), and septic shock (17.6%). KRT was initiated in 112 (36%) patients, and 66 (21.2%) patients died during the follow-up. The number of measured sK^+ was similar among the groups (3.5 ± 2 , 3.6 ± 2 , 3.8 ± 2 , 4.3 ± 2 , 2.7 ± 1 , 4.4 ± 2 , 3.9 ± 2 , and 3.0 ± 1 , respectively).

sK^+ trajectories and hospital mortality

Among 311 AKI patients, 66 (21.2%) die during the hospitalization. No differences were found on overall survival between patients with normoK and dyskalemia (85.2%; 95% CI 0.78 to 0.92 vs 71.5%; 95% CI 0.65 to 0.78, respectively); Log-Rank Test $P = 0.01$ (Fig. 3). Sixteen (5.1%) patients died with normoK, 4 (1.2%) in corrected hyperK, 3 (0.9%) in corrected hypoK, 19 (6.1%) in fluctuating potassium, 2 (0.6%) patients in uncorrected hypoK, 3 (0.9%) in normoK to hypoK, 6 (1.9%) in normoK to hyperK, and 13 (4.1%) in uncorrected hyperK. Based on Kaplan-Meier plots, the 10-days hospital survival was 85.2% (CI 95% 0.78–0.92) in normoK, 85.1% (CI 95% 0.73–0.99) in corrected hyperK, 81.6% (CI 95% 0.64–1.00) in corrected hypoK, 77.9% (CI 95% 0.69–0.87) in fluctuating potassium, 71.4% (CI 95% 0.44–1.00) in uncorrected hypoK, 67.5% (CI 95% 0.43–1.00) in normoK to hypoK, 45.5% (CI 95% 0.23–0.86) in normoK to hyperK, and 27.8% (CI 95% 0.13–0.58) in uncorrected hyperK, with a log-rank test $p < 0.05$. After adjusting for potential confounders in model 2, a significantly 10-days hospital mortality were noted in normoK to hyperK (OR 1.37; 95% CI, 1.09 to 1.72, $p = 0.006$), and uncorrected hyperK (OR 1.63; 95% CI, 1.35 to 1.97, $p < 0.001$) compared with the normoK group (Table 2).

When a broad range of prespecified participant subgroups consider comorbidities and exposures that could attenuate the relationship between uncorrected hyperK and mortality, as age, gender, the presence of diabetes, hypertension, shock, sepsis, CKD, AKI KDIGO 3 and KRT, it was observed that the interactions between these variables and outcome did not modify the primary results (interaction $p = > 0.05$ for all) overall OR 1.71 (IC 95%, 1.42–2.06, $p < 0.05$) (Fig. 4)

sK^+ trajectories and KRT start

During hospitalization 112 (36%) AKI patients required KRT, including 33 (10.6%) with normoK, 11 (3.5%) with corrected hyperK, 8 (2.5%) with corrected hypoK, 39 (12.5%) with fluctuating sK^+ , 2 (0.6%) uncorrected hypoK, 3 (0.9%) normoK to hypoK, 2 (0.6%) normoK to hyperK, and 13 (4.1%) with

uncorrected hyperK. A significantly higher 10-day KRT initiation was noted in the uncorrected hyperK group when compared with the normoK group (OR 1.40; 95% CI, 1.12 to 1.75, $p = 0.003$) (Table 3).

Discussion

In this prospective cohort, we found that 60.8% of patients with AKI develop dyskalemia. These patients are more likely to die within the first 10 days of hospitalization, specifically those who had a trajectory from normoK to hyperK and those with uncorrected hyperK, where the risk is even higher, as expected, they were also at higher risk of initiating KRT.

We note that normoK to hyperK and uncorrected hyperK were associated with an increased probability of death by 37% and 63%, respectively. Compared with the normoK group, this association was not attenuated, despite considering multiple subgroups according to comorbidities and exposures.

The association of hyperK and mortality has been previously reported and is consistent with other studies. In a retrospective analysis of 932 critically ill hospitalized adults, high rates of arrhythmia and cardiac arrest occurred in patients with hyperK ≥ 6.5 mEq/L (23). In this study, AKI increased the risk of death more than two-fold. In our cohort, patients with AKI who had normoK and excess sK^+ during their hospitalization had a higher risk of died. An et al. also found that increases in sK^+ levels preceded death in critically ill patients (23). Additionally, McMahon et al. described in critically ill patients who had even minor elevations in sK^+ (to levels 4.5–5.0 meq/L) conferred an increased risk of death (24). Khanagavi et al. reported on hospitalized patients with $sK^+ > 5.1$ meq/L and AKI that the duration of hyperK increased four-fold the mortality risk. The total duration of hyperK was also associated with death (10).

The association between hyperK and mortality in patients with AKI could be driven mostly by cardiac rhythm abnormalities [25]. HyperK decreases the transmembrane potassium gradient, leading to increased potassium conductance, which shortens the duration of the action potential (26). As potassium rises from 5.5 to 6.5 mmol/L, peaked T-waves and a prolonged PR segment may be seen, along with progressive widening of the QRS complex, fascicular and bundle branch blocks, a “sine-wave” appearance, and asystole (27). However, the actual causes of death in patients with hyperK are poorly described, and the causal relationship between hyperK and outcome remains controversial (28).

We observed that more than half of our patients had dyskalemia (60.8%), a result that could be explained because, in addition to the AKI event with its respective decrease in glomerular filtration rate that explains the impairment of renal elimination of sK^+ , our cohort had patients with documented risk factors for the development of hyperK (29), such as the greater prevalence of men (58%), one-third had diabetes (33.7%), presence of patients with CKD (15.7%), almost half had sepsis (45%), including patients with cardiorenal syndrome (12.8%), and most were classified as having severe AKI (stage 3) (63.9%).

As a secondary outcome, we considered initiation of KRT by sK^+ trajectories

In our cohort, one-third of patients were started on KRT during the follow-up, and those patients in the uncorrected hyperK group had an increased risk of 40%. This is an intuitive result that is not surprising, since kiperK is a frequent indication for the initiation of KRT in patients with AKI (30, 31), especially if there is no decrease in hyperK, despite treatment (32). However, the sK^+ concentration that should serve as a trigger for KRT remains debated. Gaudry et al. demonstrated, in a randomized clinical trial, that a strategy of delayed KRT ultimately avoided KRT in many patients who received medical treatment for hyperK (33). Another trial evaluated hypertonic sodium bicarbonate in critically ill patients with severe acidemia ($pH < 7.2$) and reported that the intervention group had a lower sK^+ , less need for KRT, and a longer delay to initiation of KRT in those patients ultimately requiring KRT (34). Last, if strategies to correct hyperK fail, KRT is the most effective way to eliminate excess sK^+ (35). In the setting of high blood and dialysate flow and low dialysate potassium concentration, sK^+ drops within minutes of initiation, and sK^+ will decrease more slowly after 2 h of hemodialysis and rebound after stopping the therapy (28). When facing an episode of AKI, specifically when hyperK exists, all strategies should be tried to decrease sK^+ and avoid starting KRT and death. Failure of hyperK to correct by > 1.0 mEq/L within 48 h after initial measurement predicts death (24). The benefit of correction of hyperK was also observed in our cohort, when we noted that those patients in the corrected hyperK trajectory had no association with start of KRT or death during follow-up.

Interestingly, there was a higher percentage of patients with diabetes mellitus in the corrected hypoK group. It is well known that severe hyperglycemia in diabetes can cause osmotic diuresis leading to dehydration and electrolyte loss, particularly sodium, sK^+ , chloride and magnesium. Dehydration in turn induces secondary hyperaldosteronism that exacerbates sK^+ loss. The excessive use of insulin is associated with hypokalemia. On another hand, drugs like thiazide or loop diuretics, used for treating comorbid conditions like hypertension in diabetes may also cause hypokalemia (36). It is to be assumed that the correction of the hyperglycemia, as well as the suspension of these drugs during the hospitalization would correct the hypoK.

Our group showed that fluid adjustment was associated with a 42% risk reduction in initiation of KRT (37); it could be that, through this fluid adjustment, sK^+ can decrease and thus improve the clinical course of these patients. In this line, utilization of balanced solutions with physiological concentrations of chloride (Ringer's lactate and Plasmalyte) prevents the development of metabolic acidosis and is associated with lower sK^+ levels compared to NaCl 0.9% (38). Other strategies that have shown benefit by decreasing potassium in patients with AKI are calcium salts, which increase the cardiac threshold potential and stabilizes the myocellular membrane (39); hypertonic sodium solution, which increases the action potential rising velocity in isolated cardiomyocytes (40); hypertonic sodium bicarbonate (150 mL of 8.4% sodium bicarbonate over 20 min) in patients with metabolic acidosis (34); polarizing solutions, including use of insulin (41) and β -adrenergic agonists (42) to shift potassium from the extracellular to the intracellular compartment; loop diuretics, which have shown to be effective in patients with hyperK and concomitant volume overload (43); and finally, potassium-binding agents (44). It is very important to keep monitoring sK^+ levels when implementing strategies to decrease them. It is likely that there will be

rebounds with elevations after treatment, especially if the treatments used do not eliminate sK^+ . We measured sK^+ with a median of three times during a mean of 8.5 days of hospitalization. The monitoring of sK^+ levels is particularly important considering the results of our study. Since we must ensure that hyperK is corrected, we observed that the highest risk of dying was in patients with uncorrected hyperK. In line with this, it would be as important that, in patients with AKI, we carry out strategies to prevent increases in sK^+ , as it has been reported that up to 60% of cases of hyperK develop during hospitalization (23).

Our study has some **limitations**. The included cohort of patients is relatively small. We do not consider the amount of potassium administered during hospitalization, such as antibiotics, intravenous fluids, and enteral or parenteral diet. This contribution could have modified its trajectory, neither the strategies that could have decreased sK^+ . We believe that it would be practically impossible to calculate the exact amount of potassium that is administered to a patient in these scenarios.

The 10-day follow-up during hospitalization was short, but it has been shown that most patients who required KRT had initiation of KRT within a short follow-up period (45). Due to the observational nature of the investigation, the causal relationship between dyskalemia and clinical outcomes could not be established. Thus, our investigation solely serves as a hypothesis-generating study. Although we adjusted for known common variables associated with the studied outcomes, unmeasured confounding could not be completely ruled out. Some rare sK^+ trajectories were not considered for our study, although we tried to capture those that seemed most relevant to the study's objectives. Finally, we did not report the specific management strategies that were used for sK^+ level correction.

One of the **strengths** of our cohort lies in its prospective nature, since most of the data on hyperK and mortality are retrospective cohorts (29). To the best of our knowledge, this is the first time that a study was able to dissect the trajectory of sK^+ levels in patients with AKI, and with this, we obtained a better perspective of which patients are most susceptible to death.

Conclusion

We found that, during AKI, 60.8% of patients develop dyskalemia, and these patients are more likely to die, specifically those who had a trajectory from normoK to hyperK and those with uncorrected hyperK.

List Of Abbreviations

AKI, acute kidney injury; CKD, Chronic Kidney Disease; HyperK, hyperkalemia; sK^+ serum potassium; KDIGO, Kidney Disease Improving Global Outcomes; KRT, Kidney Replacement Therapy; MDRD-4, Modification of Diet in Renal Disease Study equation; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology, PCO_2 , partial pressure of carbon dioxide, PO_2 , partial pressure of oxygen.

Declarations

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Statement of Ethics The study was conducted in adherence with the Declaration of Helsinki.

Study approval statement: The study was approved by Hospital Civil de Guadalajara Fray Antonio Alcalde Institutional Review Board (HCG/CEI-0550/15)

Consent to participate statement: Written informed was obtained in all participants.

Consent to publication: not applicable.

Data Availability Statement: Data is available if someone do the requirements, could be found in the electronic files of the Hospital Civil de Guadalajara Fray Antonio Alcalde

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Authors' Contributions: JSCI, PMA, AAGQ designed the study, recruited and analyzed data, made tables and figures and wrote the manuscript. RCDL, OVV, SRLG wrote the manuscript; GCA, AEOM, BDV, CECG, DGB, MAN, FMDM, GNB, RMG, MIH recolected data and GGG supervice all the process.

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Tables

Table 1 is available in the Supplementary Files section.

Table 2. The association between sK^+ trajectories and 10-days mortality.

Potassium trajectories	Model 1 ^a		Model 2 ^b	
	OR (95% CI)	P value	OR (95% CI)	P value
NormoK	1 (reference)	-	1 (reference)	-
Corrected hyperK	0.92(0.78-1.07)	0.30	0.97(0.83-1.13)	0.71
Corrected hypoK	0.94(0.77-1.14)	0.54	0.91(0.75-1.10)	0.36
Fluctuating K	0.99(0.89-1.09)	0.85	0.92(0.83-1.02)	0.15
Uncorrected hypoK	1.03(0.77-1.38)	0.79	1.03(0.77-1.36)	0.83
NormoK to hypoK	1.06(0.83-1.36)	0.62	1.01(0.79-1.28)	0.93
NormoK to hyperK	1.34(1.06-1.70)	0.01*	1.37(1.09-1.72)	0.006*
Uncorrected hyperK	1.71(1.42-2.06)	<0.001*	1.63(1.35-1.97)	<0.001*

^a Model 1: unadjusted

^b Model 2: adjusted for age, sex, gender, diabetes mellitus, hypertension, smoking, hypothyroidism, chronic kidney disease, cerebrovascular disease, ischemic cardiopathy, sepsis, hypovolemia, cardiorenal syndrome, nephrotoxic, shock, AKI Stage, and KRT

Table 3. The association between sK⁺ trajectories and KRT start.

Serum Potassium trajectories	Model 1 ^a		Model 2 ^b	
	OR (95% CI)	P value	OR (IC 95%)	P value
NormoK	1 (reference)	-	1 (reference)	-
Corrected hyperK	1.02(0.84-1.22)	0.83	0.96(0.80-1.15)	0.71
Corrected hypoK	1.06(0.85-1.33)	0.57	1.09(0.87-1.36)	0.41
Fluctuating K	1.09(0.97-1.22)	0.13	1.06(0.94-1.19)	0.32
Uncorrected hypoK	0.89(0.63-1.25)	0.50	0.93(0.67-1.30)	0.70
NormoK to hypoK	0.91(0.68-1.21)	0.53	1.00(0.75-1.33)	0.97
NormoK to hyperK	0.89(0.67-1.17)	0.41	0.88(0.68-1.15)	0.38
Uncorrected hyperK	1.46(1.17-1.83)	<0.001*	1.40(1.12-1.75)	0.003*

^a Model 1: unadjusted

^b Model 2: adjusted for age, sex, gender, diabetes mellitus, hypertension, smoking, hypothyroidism, chronic kidney disease, cerebrovascular disease, sepsis, hypovolemia, cardiorenal syndrome, nephrotoxic, shock, and AKI Stage

Figures

Figure 1

Serum Potassium groups

Figure 2

Flowchart of study population

Figure 3

Kaplan-Meier survival estimates at 10-day follows up between normoK vs dyskalemia.

Figure 4

OR of unadjusted 10-days mortality in different subgroups of patients with uncorrected hyperK

Supplementary Files

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