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ORIGINAL RESEARCH

Changes in potassium level and renal function with balanced crystalloid administration in the emergency department

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Abstract

A common reason that often makes clinicians hesitate to use balanced crystalloids in the emergency department is the risk of unexpected hyperkalemia in patients with decreased renal function. In this single-center retrospective cohort study, we compared the change in potassium levels before and after administrating a balanced crystalloid, Plasma Solution A, in patients with normal and decreased renal function. Patients who were administered Plasma Solution A and had an electrolyte follow-up potassium test within 24 hours were included. Decreased renal function was defined as an estimated glomerular filtration rate (eGFR) of less than 90 mL/min/1.73 m^2. A total of 1134 patients were included, comprising 376 patients with normal renal function (an eGFR $>$90 mL/min/1.73 m^2) and 758 patients with decreased renal function. In patients with decreased renal function, the mean administered Plasma Solution A volume (mL/kg, mean (SD)) was 34.0 (20.1). The mean administration duration (hr, mean (SD)) was 13.9 (4.7). The eGFR (mL/min/1.73 m^2, mean (SD)) increased from 52.6 (24.4) to 68.0 (37.6) ($p < 0.05$), and the potassium level (mmol/L, mean (SD)) decreased from 4.4 (0.6) to 4.1 (0.6) ($p < 0.05$). Altogether, we found that the potassium level and renal function may not be worsened in patients with decreased renal function within 24 hours after the intravenous administration of approximately 2 L of a balanced crystalloid in the emergency department.

Keywords

Potassium; Renal function; Balanced crystalloid; Emergency department

1. Introduction

The intravenous administration of an isotonic crystalloid is one of the most common and essential treatments in the emergency department (ED) to re-establish hemodynamic stability and hydration, replace fluid losses and maintain intravascular volume. The most commonly used crystalloid is saline [1], but because the chloride concentration of saline is 154 mmol/L, it can cause hyperchloremic metabolic acidosis and worsen renal perfusion [2, 3], which also raises the possibility of delayed recovery from acute illnesses [4, 5].

Previous trials compared the treatment effects of saline with a balanced crystalloid solution, either Ringer's solution (109 mmol/L) or Plasma-Lyte (98 mmol/L) [6–8], which have chloride concentrations that are physiologically similar to human plasma. In a multicenter trial comprising hospitalized patients and those treated in an intensive care unit (ICU), it was found that patients treated with a balanced crystalloid had better outcomes in terms of mortality and major adverse kidney events, including dialysis and persistent renal dysfunction [6]. A more recent study reported no significant difference in outcomes for ICU patients and that the benefits of balanced crystalloid administration might not be significant in ICU patients who require long-term intensive care [7]. However, an extensive study on ED patients who were not admitted to the ICU showed a significantly better outcome in terms of mortality, new renal replacement therapy and persistent renal dysfunction in favor of treatment with balanced crystalloids [8]. Considering that most patients visiting the ED do not require admission to the ICU and given the widespread use of balanced crystalloids in large populations, even slight differences in the risk of kidney injury or mortality might have significant public health implications. Additionally, it was reported that balanced crystalloids might have more advantages in helping patients recover from illness [8].

Although no absolute contraindications exist for selecting balanced crystalloids as a resuscitation fluid, clinicians may hesitate to use them due to their possibility of inducing undesired hyperkalemia [9, 10], especially in patients with decreased renal function, due to the potassium contained in balanced crystalloids, including Ringer's solution (4 mmol/L) and Plasma-Lyte (5 mmol/L). Previous studies have demonstrated that balanced crystalloids could yield better outcomes in elec-

trolyte control than saline, but these outcomes were inconsistent across several studies [11–15]. In the secondary analysis of a clinical trial, the use of balanced crystalloids was not associated with an increased incidence of severe hyperkalemia and was associated with a significantly lower incidence of RRT among patients with hyperkalemia at ICU admission and patients with acute kidney injury at ICU admission [16]. However, the changes in the plasma potassium level and renal function with balanced crystalloid administration in ED patients according to renal function have not yet been reported.

In this study, we compared the change in potassium levels before and after administrating balanced crystalloid Plasma Solution A, a generic of Plasma-Lyte, between patients with normal and decreased renal function and also evaluated risk factors for increased potassium levels after administering Plasma Solution A.

2. Materials and Methods

2.1 Study Design

This retrospective cohort study compared the changes in potassium levels and renal function in ED patients with normal and decreased renal function. The patients were given Plasma Solution A, which contained 140 mmol/L sodium, 5 mmol/L potassium, 1.5 mmol/L magnesium, 98 mmol/L chloride, 27 mmol/L acetate, and 23 mmol/L gluconate. We retrieved and assessed the data of patients (aged $\geq$18 years) who visited the ED of an educational hospital between 01 January 2019, and 30 June 2022.

2.2 Inclusion and exclusion criteria

Patients were eligible if they had received intravenous Plasma Solution A and had a potassium electrolyte follow-up test within 24 hours of administering Plasma Solution A. Patients previously diagnosed with end-stage renal disease (ESRD) on dialysis and chronic kidney disease (CKD) were excluded because it was difficult to determine whether it would be safe to use balanced crystalloid rather than saline in these patients who have chronic tubular dysfunction due to the risk of impaired potassium excretion capacity and fluid administration was often restricted because of electrolyte abnormalities. Patients who received potassium-containing fluids (parenteral nutrition, potassium chloride or potassium phosphate in 5% dextrose or sodium chloride for potassium replacement and 5% dextrose plus 0.45% sodium chloride and 0.15% potassium chloride solution) were excluded. Patients who received insulin or beta-blockers were also excluded because these treatments could affect potassium levels by shifting potassium to the intracellular or extracellular space, as well as those who received polystyrene or intravenous furosemide because polystyrene is a potassium-binding resin commonly used to reduce potassium levels, and furosemide can induce renal loss of potassium. Every oral medication, including angiotensin receptor blockers, angiotensin-converting enzyme inhibitors, thiazide, spironolactone, and furosemide, was held during the study period.

2.3 Data collection and subgroups

We collected their vital signs data, blood urea nitrogen (BUN) levels, creatinine (Cr) levels, initial electrolyte levels, follow-up electrolyte levels, and histories of underlying diseases such as hypertension, diabetes mellitus and chronic kidney disease from our hospital's electronic health records. Their glomerular filtration rate (GFR) was estimated using the Modification of Diet in Renal Disease (MDRD) Study equation [estimated GFR MDRD = 186 $\times$ serum creatinine (mg/dL)$^{-1.154}$ $\times$ age$^{-0.203}$ $\times$ (0.742 if female)] [17]. Patients with decreased renal function were defined as those who met the criteria for stage 2 or greater kidney damage according to the following Kidney Disease: Improving Global Outcomes (KDIGO) guidelines; stage 1, a GFR $\geq$90 mL/min per 1.73 m^2; stage 2, a GFR of 60–89 mL/min per 1.73 m^2; stage 3, a GFR of 30–59 mL/min per 1.73 m^2; stage 4, a GFR of 15–29 mL/min per 1.73 m^2; and stage 5, a GFR $<$15 mL/min per 1.73 m^2 [18]. Subgroups were classified as follows according to eGFR values and KDIGO stages: Group 1, normal renal function and an eGFR $\geq$90 mL/min per 1.73 m^2; Group 2, mildly decreased renal function and an eGFR of 60 to 90 mL/min per 1.73 m^2; Group 3, moderately decreased renal function and an eGFR of 30 to 60 mL/min per 1.73 m^2; and Group 4, severely decreased renal function and an eGFR $<$30 mL/min per 1.73 m^2.

2.4 Outcomes

The primary outcome was based on comparing the changes in potassium levels and renal function before and within 24 hours after Plasma Solution A administration between patients with normal and decreased renal function. The secondary outcome was based on evaluating the risk factors for increased potassium levels after the administration of Plasma Solution A.

2.5 Statistical analysis

We summarized the clinical characteristics of the patients using means and standard deviations (SDs) for normally distributed variables and counts (with percentage) for categorical variables. For our primary outcome, we used a paired *t*-test to evaluate the patients' potassium level changes. For our secondary outcome, we used binomial logistic regression to evaluate risk factors for increased potassium levels after the administration of Plasma Solution A. All tests were two-sided, and p values $\leq$ 0.05 were considered statistically significant. All statistical analyses were performed using the IBM SPSS ver. 27.0 software (IBM Co., Armonk, NY, USA).

3. Results

3.1 Participant characteristics

A total of 2051 patients were reviewed, and 1134 were found eligible for this study. Of the included patients, 376 had normal renal function, and 758 had decreased renal function (Fig. 1). Their mean age (SD) in each group was 61.9 (14.9) years and 70.7 (13.8) years, mean (SD) creatinine level was 0.6 (0.1) mg/dL and 1.7 (1.7) mg/dL, eGFR was 123.3 (36.4) mL/min/1.73 m^2 and 52.6 (24.4) mL/min/1.73 m^2, and potassium level was 4.1 (0.4) mmol/L and 4.4 (0.6) mmol/L,

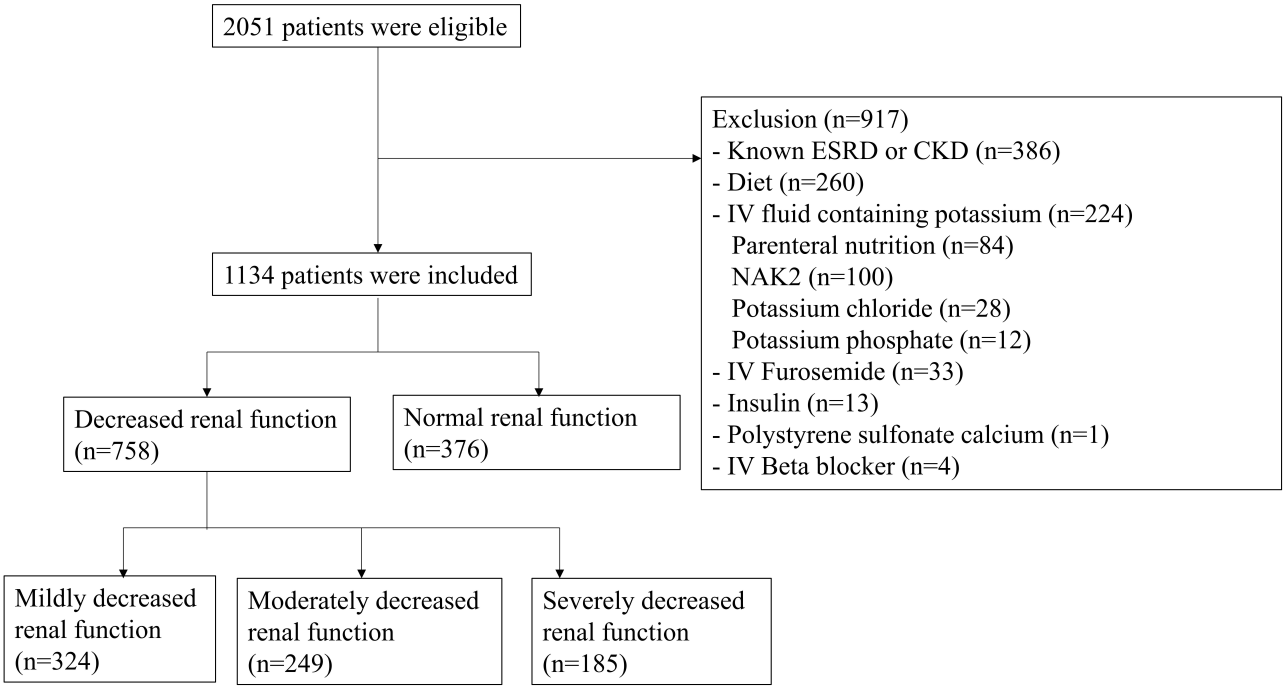

FIGURE 1. Patient enrollment. ESRD: end stage renal disease; CKD: chronic kidney disease; IV: intravenous; NAK2: Dextrose 5% water with Na+ 77 mEq and K+ 20 mEq. Normal renal function, eGFR ≥90 mL/min per 1.73 m^2, mildly decreased renal function, eGFR 60 to 90 mL/min per 1.73 m^2, moderately decreased renal function, eGFR 30 to 60 mL/min per 1.73 m^2, severely decreased renal function, eGFR <30 mL/min per 1.73 m^2.

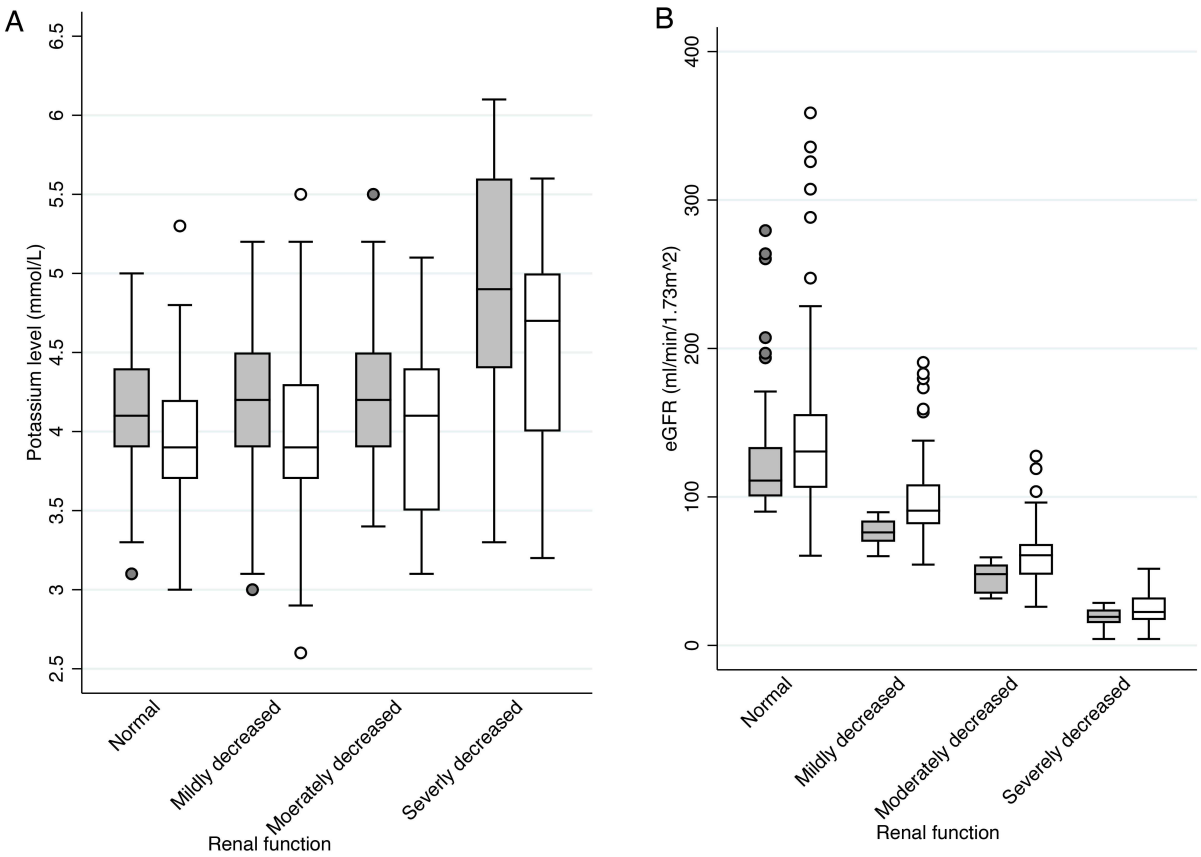

FIGURE 2. Changes in potassium levels and renal function in patients with normal and decreased renal function. eGFR, estimated glomerular filtration rate.

respectively. The mean (SD) values for the administered Plasma Solution A volumes were 29.0 (15.4) L and 34.0 (20.1) L, and the mean (SD) duration of infusion was 14.4 (4.5) hours and 13.9 (4.7) hours, respectively (Table 1).

A subgroup of patients with decreased renal function is also described according to eGFR values in Table 2. We found that 324 patients had mildly decreased renal function, 249 patients had moderately decreased renal function, and 185 patients had severely decreased renal function. Their mean (SD) of eGFR values were 76.5 (8.5) mL/min/1.73 m^2, 46.0 (9.2) mL/min/1.73 m^2 and 19.6 (0.8) mL/min/1.73 m^2, and their mean (SD) of potassium levels were 4.2 (0.5) mmol/L, 4.2 (0.5) mmol/L and 4.9 (0.8) mmol/L, respectively. The administered mean (SD) volume of Plasma Solution A was 14.1 (4.9) mL/kg, 13.5 (5.0) mL/kg and 13.5 (4.1) mL/kg for 14.1 hours, 13.5 hours, and 13.5 hours, respectively.

3.2 Primary outcomes: changes in potassium levels and renal function

Here, we investigated the continuity of the electrolyte, BUN, and Cr levels in each group and found that all levels had good continuity. Our results showed a decrease in the potassium levels (Fig. 2A) and an increase in the eGFR levels (Fig. 2B) in patients with normal renal function and decreased renal function. The potassium level decreased by 0.2 mmol/L, and the eGFR increased by 17.9 mL/min/1.73 m^2 in patients with normal renal function. The potassium level decreased by 0.3 mmol/L, and the eGFR value increased by 15.4ß mL/min/1.73 m^2 in patients with decreased renal function.

The potassium levels and eGFR values were significantly changed in patients with mildly, moderately and severely decreased renal function, respectively. The potassium level decreased by 0.3 mmol/L and the eGFR increased by 20.9 mL/min/1.73 m^2 in patients with mildly decreased renal function. The potassium level decreased by 0.1 mmol/L and the eGFR increased by 15.4 mL/min/1.73 m^2 in patients with moderately decreased renal function. Comparatively, in patients with severely decreased renal function, their potassium level decreased by 0.3 mmol/L and eGFR increased by 5.9 mL/min/1.73 m^2 (Table 3).

3.3 Secondary outcome: Risk factors for increased potassium levels

The potassium levels increased in 223 patients after the administration of Plasma Solution A, from 4.0 $\pm$ 0.3 mmol/L to 4.4 $\pm$ 0.4 mmol/L (Table 4), but hyperkalemia (>5.5 mmol/L) did not occur in these patients despite Plasma Solution A administration, while their levels of sodium and chloride were significantly increased. Multivariable logistic regression showed that male sex, hypertension, BUN and Cr might be independent risk factors for increased potassium levels (Table 5).

4. Discussion

The Surviving Sepsis Campaign recommended using a balanced crystalloid rather than saline [19], and a previous study in an ED showed that balanced crystalloids led to better renal outcomes than saline [8]. However, some clinicians still hesitate to use balanced crystalloids because of the associated risk of unexpected hyperkalemia in patients with decreased renal function [9, 10]. However, there is limited literature on the changes in potassium levels with balanced crystalloid administration in ED patients with decreased renal function. After excluding patients with CKD or ESRD, we analyzed the data of patients with acute renal dysfunction. This study evaluated the changes in plasma potassium levels and renal function with balanced crystalloid administration (Plasma Solution A). We found that the potassium levels did not increase significantly to cause severe hyperkalemia and the renal function was not significantly worsened within a day in ED patients with decreased renal function. Although several patients had increased sodium and chloride levels, the increase was small and no patient had clinically significant electrolyte abnormalities. These findings provide a basis for using a balanced crystalloid without determining the eGFR and having undue concern about hyperkalemia in ED. Our results also suggested that a balanced crystalloid might be safe and that the acid-base effects of fluid could be more important for potassium homeostasis than the relatively small amount of potassium in these fluids.

Several reasons could explain the non-significant change in potassium levels after administering Plasma Solution A. First, the amount of potassium in Plasma Solution A at 5 mmol/L could have been negligible when distributed throughout the body, considering that 98% of the body's total potassium is stored inside cells. This means that the intracellular to extracellular potassium shift might have a much more significant impact on serum potassium than the 5 mmol/L potassium in Plasma Solution A. Additionally, hyperchloremic acidosis caused by saline would cause potassium to shift out of cells and increase serum potassium. Second, a potassium intake of 90 mmol/day could be adequate for healthy adults [20], corresponding to approximately 4 mmol of potassium per hour. Thus, 5 mmol/L potassium in Plasma Solution A might be necessary to maintain adequate potassium levels. Third, based on the results of our study, we could assume that if urine output is maintained during hydration, potassium excretion may increase, and potassium levels may not rise. Lastly, it could be a logical conclusion that post-infusion serum potassium concentration would be trended toward that of the infused solution. If the initial K level was 6.0 mmol/L, the post-infusion level should be lower than 6.0 if mixed with a solution containing 5.0 mmol/L potassium. These concepts and related evidence were summarized in a review article by Gupta *et al.* [21].

This study had several limitations. First, it was a retrospective study comprising a relatively small sample size of severely decreased renal function patients (n = 185). This could be partly explained by the exclusion of 917 patients based on the exclusion criteria of various factors that might have possibly affected the potassium level in addition to the fluid. Thus, a prospective with a larger sample size of patients with severely decreased renal function is needed to confirm these findings. Second, according to our results, the levels of Cr decreased and eGFR increased in all patients with decreased renal function after the administration of Plasma Solution A. Logistic regression of risk factor of increasing potassium level also

TABLE 1. Patients' demographics: normal and decreased renal function.

	Normal renal function (n = 376)	Decreased renal function (n = 758)	*p* value
Male sex, n (%)	188 (50.0)	403 (53.2)	0.315
Age, mean (SD), yr	61.9 (14.9)	71.7 (13.8)	<0.001
Height, mean (SD), cm	161.9 (9.4)	161.3 (9.3)	0.301
Weight, mean (SD), kg	59.4 (13.6)	60.1 (13.4)	0.429
Hypertension, n (%)	140 (37.2)	333 (43.9)	0.031
Diabetes mellitus, n (%)	76 (20.2)	313 (41.3)	<0.001
Systolic blood pressure, mean (SD), mmHg	128.9 (26.3)	127.6 (29.5)	0.467
Diastolic blood pressure, mean (SD), mmHg	72.6 (16.9)	68.0 (18.5)	<0.001
Mean blood pressure, mean (SD), mmHg	92.5 (19.0)	89.0 (21.6)	0.008
Pulse rate, mean (SD)/min	96.7 (18.7)	99.2 (20.8)	0.059
Respiratory rate, mean (SD)/min	19.6 (4.9)	20.7 (4.7)	<0.001
Body temperature, mean (SD), °C	37.1 (0.9)	37.2 (1.1)	0.017
BUN, mean (SD), mg/dL	13.8 (6.6)	30.9 (23.8)	<0.001
Creatinine, mean (SD), mg/dL	0.6 (0.1)	1.7 (1.7)	<0.001
eGFR-MDRD, mean (SD), mL/min/1.73 m^2	123.3 (36.4)	52.6 (24.4)	<0.001
Sodium, mean (SD), mmol/L	137.5 (4.0)	138.0 (4.8)	0.141
Potassium, mean (SD), mmol/L	4.1 (0.4)	4.4 (0.6)	<0.001
Chloride, mean (SD), mmol/L	102.5 (4.9)	102.6 (6.1)	0.927
Volume of Plasma Solution A, mean (SD), mL/kg	29.0 (15.4)	34.0 (20.1)	<0.001
Time interval, mean (SD), hour	14.4 (4.5)	13.9 (4.7)	0.082

SD, standard deviation.

TABLE 2. Baseline values of patients with decreased renal function.

	Mildly decreased renal function[a] (n = 324)	Moderately decreased renal function[b] (n = 249)	Severely decreased renal function[c] (n = 185)
BUN, mean (SD), mg/dL	19.1 (7.5)	27.4 (10.6)	56.4 (35.2)
Creatinine, mean (SD), mg/dL	0.9 (0.2)	1.4 (0.3)	3.4 (2.7)
eGFR-MDRD, mean (SD), mL/min/1.73 m^2	76.5 (8.5)	46.0 (9.2)	19.6 (7.0)
Sodium, mean (SD), mmol/L	138.3 (4.3)	138.2 (4.4)	137.5 (4.0)
Potassium, mean (SD), mmol/L	4.2 (0.5)	4.2 (0.5)	4.9 (0.8)
Chloride, mean (SD), mmol/L	103.4 (4.8)	103.4 (6.2)	100.2 (7.4)
Plasma Solution A, mean (SD), L	1.9 (1.3)	2.3 (1.6)	2.0 (1.1)
Plasma Solution A, mean (SD), mL/kg	29.7 (20.2)	42.6 (34.9)	39.4 (21.7)
Duration of injection, mean (SD), hour	14.1 (4.9)	13.5 (5.0)	13.5 (4.1)

SD, standard deviation; BUN: blood urea nitrogen; eGFR-MDRD: estimated glomerular filtration rate- Modification of Diet in Renal Disease.

[a]: Mildly decreased renal function, eGFR 60 to 90 mL/min per 1.73 m^2.

[b]: moderately decreased renal function, eGFR 30 to 60 mL/min per 1.73 m^2.

[c]: severely decreased renal function, eGFR <30 mL/min per 1.73 m^2.

TABLE 3. Changes in potassium and renal function at the follow-up test within 24 hours.

	Initial level, mean (SD)	Follow-up level, mean (SD)	95% CI of mean difference	*p* value
Normal renal function (n = 376)				
Sodium (mmol/L)	137.5 (4.0)	139.2 (3.7)	1.43 to 1.96	<0.001
Potassium (mmol/L)	4.1 (0.4)	3.9 (0.4)	0.12 to 0.20	<0.001
Chloride (mmol/L)	102.5 (4.9)	104.1 (4.9)	1.01 to 2.07	<0.001
BUN (mg/dL)	13.8 (6.6)	12.8 (5.4)	0.59 to 1.46	<0.001
Creatinine (mg/dL)	0.6 (0.1)	0.6 (0.2)	0.03 to 0.06	<0.001
eGFR-MDRD (mL/min/1.73 m^2)	123.3 (36.4)	141.2 (56.0)	14.1 to 21.8	<0.001
All decreased renal function (n = 758)				
Sodium (mmol/L)	138.0 (4.9)	139.5 (4.7)	1.34 to 1.73	<0.001
Potassium (mmol/L)	4.4 (0.6)	4.1 (0.6)	0.21 to 0.26	<0.001
Chloride (mmol/L)	103.1 (5.5)	104.9 (4.7)	1.32 to 2.30	<0.001
BUN (mg/dL)	30.9 (23.8)	29.0 (24.0)	1.53 to 2.24	<0.001
Creatinine (mg/dL)	1.7 (1.7)	1.5 (1.7)	0.18 to 0.21	<0.001
eGFR-MDRD (mL/min/1.73 m^2)	52.6 (24.4)	68.0 (37.6)	13.8 to 17.0	<0.001
Mildly Decreased renal function (n = 324)				
Sodium (mmol/L)	138.2 (4.4)	139.5 (3.7)	0.97 to 1.66	<0.001
Potassium (mmol/L)	4.2 (0.5)	3.9 (0.5)	0.20 to 0.29	<0.001
Chloride (mmol/L)	103.4 (4.8)	105.2 (4.1)	1.25 to 2.47	<0.001
BUN (mg/dL)	19.1 (7.5)	17.3 (6.2)	1.34 to 2.28	<0.001
Creatinine (mg/dL)	0.9 (0.2)	0.8 (0.2)	0.12 to 0.15	<0.001
eGFR-MDRD (mL/min/1.73 m^2)	76.5 (8.5)	97.4 (28.6)	17.8 to 23.9	<0.001
Moderately Decreased renal function (n = 249)				
Sodium (mmol/L)	138.2 (4.4)	137.1 (6.1)	0.92 to 1.81	<0.001
Potassium (mmol/L)	4.2 (0.5)	4.1 (0.5)	0.09 to 0.18	<0.001
Chloride (mmol/L)	103.4 (6.2)	105.2 (5.4)	1.0 to 2.71	0.003
BUN (mg/dL)	27.4 (10.6)	24.9 (8.2)	1.85 to 3.28	<0.001
Creatinine (mg/dL)	1.4 (0.3)	1.2 (0.5)	0.16 to 0.23	<0.001
eGFR-MDRD (mL/min/1.73 m^2)	45.9 (9.2)	61.3 (24.3)	13.1 to 17.6	<0.001
Severely Decreased renal function (n = 185)				
Sodium (mmol/L)	137.5 (4.0)	139.2 (3.7)	1.43 to 1.96	<0.001
Potassium (mmol/L)	4.9 (0.8)	4.6 (0.7)	0.28 to 0.40	0.023
Chloride (mmol/L)	100.2 (7.4)	101.5 (5.5)	−1.10 to 3.76	0.252
BUN (mg/dL)	56.4 (35.2)	55.7 (36.4)	0.40 to 1.81	0.002
Creatinine (mg/dL)	3.4 (2.7)	3.1 (2.7)	0.25 to 0.36	<0.001
eGFR-MDRD (mL/min/1.73 m^2)	19.6 (7.0)	25.5 (13.8)	4.51 to 7.30	<0.001

SD, standard deviation; CI, confidence interval; eGFR-MDRD: estimated glomerular filtration rate-Modification of Diet in Renal Disease.

TABLE 4. Changes in electrolytes and renal function at the follow-up test within 24 hours in patients with increased potassium level.

	Initial level, mean (SD)	Follow-up level, mean (SD)	95% CI of mean difference	*p* value
Patients with increased potassium level (n = 223)				
Sodium (mmol/L)	138.0 (4.1)	139.6 (4.1)	1.27 to 1.87	<0.001
Potassium (mmol/L)	4.0 (0.3)	4.4 (0.4)	0.28 to 0.35	<0.001
Chloride (mmol/L)	102.8 (5.1)	104.6 (4.6)	1.50 to 2.10	<0.001
BUN (mg/dL)	17.8 (9.9)	17.6 (6.0)	−0.36 to 0.79	0.945
Creatinine (mg/dL)	1.04 (0.60)	0.99 (0.64)	0.03 to 0.74	<0.001
eGFR-MDRD (mL/min/1.73 m^2)	89.0 (50.5)	98.1 (57.5)	6.35 to 12.12	<0.001

SD, standard deviation; CI, confidence interval; eGFR-MDRD: estimated glomerular filtration rate-Modification of Diet in Renal Disease.

TABLE 5. Logistic regression analysis of risk factor for increasing potassium level.

	Univariable analysis			Multivariable analysis		
	OR	95% CI	*p* value	OR	95% CI	*p* value
Male sex	0.62	0.46 to 0.84	0.002	0.59	0.43 to 0.81	0.001
Age	0.96	0.98 to 0.99	0.002	1.00	0.99 to 1.01	0.633
Hypertension	0.64	0.47 to 0.87	0.004	0.66	0.47 to 0.93	0.016
Diabetes mellitus	1.14	0.84 to 1.55	0.387			
BUN	0.96	0.94 to 0.97	<0.001	0.94	0.92 to 0.96	<0.001
Creatinine	0.70	0.57 to 0.86	0.002	1.60	1.18 to 2.16	0.003
eGFR-MDRD	1.01	1.00–1.01	<0.001	1.00	1.00 to 1.01	0.331
Sodium	1.01	0.98–1.05	0.475			
Chloride	1.01	0.98–1.03	0.434			

OR, odds ratio; CI, confidence interval; eGFR-MDRD: estimated glomerular filtration rate-Modification of Diet in Renal Disease.

showed the protective effect of high BUN levels, suggesting the high possibility of pre-renal acute kidney injury. In other words, perfusion was improved by infusing Plasma Solution A, which further reduced the risk of hyperkalemia. Since we did not evaluate the patients' final diagnoses of kidney diseases, it is questionable whether Plasma Solution A can be used safely in patients who visit the ED due to conditions other than dehydration-related diseases. Lastly, due to the retrospective design of this study, we did not have enough data to evaluate the hourly effects of balanced crystalloid administration in ED patients.

5. Conclusions

The potassium level and renal function of patients with decreased renal function may not significantly worsen within 24 hours after the intravenous administration of approximately 2 L of a balanced crystalloid. These findings suggest that a balanced crystalloid could be safely used as a standard fluid in patients with decreased renal function in ED settings.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

SSK and HSK—Conceptualization, Data curation, Writing-original draft; SSK—Formal analysis; HSK—Investigation, Supervision; JHL and DBS—Methodology; JHL, DBS, SSK and HSK—Writing-review & editing.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Seoul National University Bundang Hospital Institutional Review Board (IRB No. B-2008-630-109) approved the study and waived the requirement for informed consent.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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