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Original Article

Dialysis in Critically Ill Patients with Hypokalemia: A Challenge to Beat by Adjusting Potassium Bath in Dialysate

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ABSTRACT

Acute renal injury (ARI) is common in critically ill patients and frequently makes renal replacement therapy necessary. Low serum potassium level is associated with arrhythmias and mortality in critically ill patients. Adjusting dialysate fluid potassium to higher level helps preventing post hemodialysis hypokalemia. **Objective:** To establish role of high potassium dialysate in management of hypokalemia in critically ill patients undergoing renal replacement therapy for ARI. **Methods:** We did a pilot study and performed a cohort on critically ill patients who developed acute renal injury and required renal replacement therapy for acute indications. We designed two groups each consisting 50 patients. Control group underwent hemodialysis with conventional dialysate. For interventional group, we added potassium bath of 3.0meq/l. Pre and post hemodialysis serum potassium levels were measured results mentioned in the form of bar chart. **Results:** For intervention group mean pre and post hemodialysis serum potassium levels were 3.43±0.36mg/dl and 4.45±5.00mg/dl respectively with no statistically significant difference in pre and post hemodialysis potassium (p=0.156). While, for control group mean pre and post hemodialysis serum potassium levels were 3.69±0.38mg/dl and 2.97±0.29mg/dl respectively. Difference in pre-post mean serum potassium in control group was statistically significant (p<0.001). Furthermore, three patients in control group developed atrial fibrillation in which hypokalemia was confirmed by laboratory testing. **Conclusions:** Acute dialysis in critical care on hypokalemic patients can be performed safely by adjusting potassium bath in dialysate.

INTRODUCTION

Critical illness is a challenging condition that affects multiple organ systems in life-threatening as well as organ-threatening manner. Kidney involvement occurs in critical illness with various clinical manifestations, of which acute kidney injury and electrolyte imbalance are two commonly encountered disorders [1, 2]. The whole of the homeostatic mechanism is altered during critical illness and there is a surge of stress hormones including corticosteroids, sympathetic system hormones, and renin-angiotensin axis hormones [3]. Circulatory collapse and low blood pressure in intensive care unit (ICU) patients is a direct stimulator for renin-angiotensin release [4]. This angiotensin rich milieu cause aldosterone release [5]. The altered hormonal taste of the body during critical illness is one among the other explanations for electrolyte imbalance in this group of patients. Likewise, ARI during critical illness is multifactorial. Drug-induced ARI and acute tubular necrosis are common reasons for ARI in the ICU. Despite being one of the common organ dysfunctions in critically ill patients, little data is available that can predict the ARI progression and prognosis in ICU patients. ARI when required dialysis is associated with greater mortality [6]. Serum electrolytes have been studied as prognostic markers and reports have shown that dysnatremia (hyponatremia/ hypernatremia) and the dyskalemia (hypokalemia/hyperkalemia), both are associated with severity and poor prognosis of ARI in ICU patients [7,8]. In ICU patients affected by COVID-19 infection, hypokalemia

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was the frequent lab abnormality that was increasing potentially fatal arrhythmia in COVID-19 patients [9, 10]. Hypokalemia in patients admitted to the emergency department with ARI was associated with adverse outcomes [11]. Dyskalemia at the time of hospital admission in patients with ARI increases one-year mortality [12]. Life-threatening cardiac arrhythmias related to hypokalemia are one of the causes of increased mortality[13].

ARI with hypokalemia when required dialysis in ICU patients offers a challenge to intensivists since dialysis worsens hypokalemia and hence the chances of related life-threatening arrhythmia. We examined the effect of high potassium dialysis on the serum potassium level of critically ill patients undergoing renal replacement therapy for acute indications and compared the results with dialysis under similar conditions with conventional dialysate. High potassium dialysis was found helpful in preventing post-dialysis hypokalemia.

METHODS

It was a prospective cohort study of a single center conducted from May 2021 to April 2022 after approval from the ethical as well as research board of the hospital *(Ref: App # 0637-2021 LNH- ERC, April 27-2021).* Data were collected by non-probability consecutive sampling technique in which we included critically ill patients requiring renal replacement therapy for acute indications. We included only those patients were included for whom written consent was obtained after a detailed explanation of the rationale and methods of the study. The study was performed at Liaquat National Hospital Karachi. Data were collected from the nephrology ICU and medical ICU. The author performed a pilot study at the same center to estimate sample size. With a confidence interval (ci) of 95% and power of error (d) = 80%, the open epi software for sample size calculation for comparing two means was used. The initial computed sample size was too small so to enhance the strength of the study, a total of 100 patients were included in the subsequent full study and divided into two groups as control vs intervention (50 in each group). All patients in both groups were undergoing hemodialysis for acute indications only. Chronic kidney disease and maintenance dialysis were considered as exclusion criteria. All patients had low serum potassium levels pre-hemodialysis (less than 3.5mg/dl). Hemodialysis prescription was similar for all patients in the two groups and was consisting high flux polysulphone dialyzer with a surface area of 1.8m2, blood flow rate of 300ml/mint, dialysate flow rate of 500ml/mint, bicarbonate solution of 36mmol/dl. However, potassium concentration was adjusted for 2 groups in the acidic part of dialysate. The control group had hemodialysis with conventional dialysate fluid with a potassium concentration of 2.0meq/liter (5.49gm). In comparison, the intervention group had a dialysate potassium concentration of 3.0meq/liter (8.23gm). A specialized proforma was designed to collect data. Information regarding the patient's biography, admission diagnosis, indication for hemodialysis, and serum potassium level pre and post-hemodialysis recorded. 2ml blood was taken from patients each time (pre and post-hemodialysis) by trained staff to measure serum potassium levels in both groups and the sample was analyzed on Cobas 501.Dialysate potassium was manually adjusted to 3.0meq/l by adding a 3.0meq/l potassium bath to the acidic solution of dialysate fluid for the intervention group only. Data were analyzed using SPSS version 25.0. Qualitative variables were presented as frequency and percentages. Quantitative variables reported as Mean±SD. Paired t-test was applied to find the mean differences. Exclusion criteria were strictly followed to avoid any confounding effect.

RESULTS

In this study, mean age of participants was 53.20 ± 17.48 years. Out of 100 patients, 52% were male and 48% were female. 42% of patients had septicemia as their admission diagnosis, 38% had complicated viral fever, 3% of patients had acute interstitial nephritis, 3% of patients had upper gastrointestinal bleeding, 3% of patients had acute pulmonary edema with severe metabolic acidosis. Other patients had diagnoses of hypertensive failure, community-acquired pneumonia, uremia, drug toxicity, lupus nephritis, and multiple myeloma with cast nephropathy. 51% of patients had DM, 65% had HTN, and 20% had ischemic heart disease as their co-morbid disease. All patients were undergoing hemodialysis for acute indication. In the study population indication for dialysis was consisting metabolic acidosis in 42% of patients, uremia in 38% of patients, and toxic ingestion in 20% of patients. The detailed descriptive characteristics of participants are shown in table 1.

Table 1: Descriptive Characteristics of Participants.

Characteristics	N (%)
Age (Years)	
Mean ± SD	53.20 ± 17.48
Gender	
Male	52 (52)
Female	48 (48)
K Bath	
Added	50 (50)
Not Added	50 (50)
Diagnosis	
Sepsis	42 (42)
Complicated Viral Fever	38 (38)
Acute Interstitial Nephritis (AIN)	3 (3)

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Acute Pulmonary Edema	3 (3)
Upper Gastrointestinal Bleed	2 (2)
Others	12 (12)
Comorbidity	
Diabetes Mellitus	51 (51)
Hypertension	65 (65)
Ischemic Heart Disease	20 (20)
Indication for Hemodialysis	
Metabolic Acidosis	42 (42)
Uremia	38 (38)
Toxic Ingestion	20 (20)

The mean pre-hemodialysis serum potassium level in the control group was 3.69±0.38mg/dl. The mean post-hemodialysis serum potassium level was 2.97 ± 0.29mg/dl. The difference in pre-post mean serum potassium in hemodialysis in the control group was statistically significant (p<0.001). Two patients in the control group developed life-threatening atrial fibrillation during the last hour of hemodialysis and responded well to immediate discontinuation of dialytic treatment without any other intervention. In both patients' hypokalemia was confirmed by laboratory testing. One patient in the control group developed atrial fibrillation just after completion of hemodialysis, in which case post hemodialysis serum potassium level was checked immediately and was found to be 2.0mg/dl. Atrial fibrillation in this patient responded well to subsequent potassium replacement. The mean pre-hemodialysis serum potassium level in the intervention group was 3.43±0.36mg/dl. The mean post-hemodialysis serum potassium level in the intervention group was 4.45±5.00mg/dl. We found a statistically insignificant difference in pre-post mean serum potassium in hemodialysis patients with k-bath intervention (p=0.156). The final findings are presented in a bar chart as shown in figure 1.

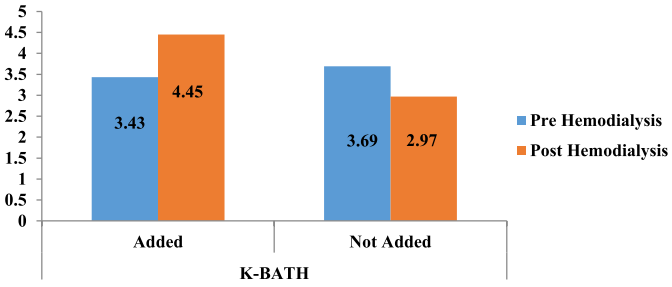

Figure 1: Comparison of Pre-Post Hemodialysis in Potassium Bath

DISCUSSION

In the present study, we enrolled ICU patients with critical illness. All patients had low or low normal pre-hemodialysis serum potassium (potassium <3.5 mEq/dl) and required urgent hemodialysis for acute indications. Acute renal injury is frequently seen complication in patients in the ICU setting and is associated with high mortality. ARI is seen in critically ill patients with septic shock, hypovolemia, drug-induced ARI, obstructive uropathy, cardiogenic shock, and major surgery. In our study, septic shock was the most common etiologic factor for ARI (47.5%) and was the most frequent cause of critical illness (42%). In literature, overall mortality associated with ARI is reported as 60.3%. ARI frequently requires dialysis [14]. As per the literature review dialysis requiring ARI is found to be associated with higher mortality (for example) as observed with ARI following percutaneous coronary intervention. ARI is frequently complicated by electrolyte imbalance. Potassium abnormalities are frequent findings of ARI. Both a rise and a drop in serum potassium levels result in various complications [15]. Hyperkalemia causes ventricular tachycardia, bradycardia, and heart block [16]. Similarly, hypokalemia causes cardiac arrhythmia, apart from muscle weakness and respiratory paralysis [17]. Certain etiologies of ARI e.g., acute tubule-interstitial nephritis, McKittrick and Wheelock syndrome [18], and leptospirosis-related ARI [19] are specifically associated with low potassium levels. Potassium is of critical importance in ICU patients. Lowest mortality in ICU patients seen with a mean potassium range between >3.5 and 4.0 mmol/l and low potassium variability [20]. Acute dialysis in ICU setup in patients with electrolyte imbalance is always a therapeutic challenge for intensive care management. Serum potassium needed to be corrected to normal or near normal by intravenous infusion of potassium chloride (KCl) solutions before or during hemodialysis which requires central line insertion and critical monitoring of serum potassium level (pre-dialysis, post dialysis, and intra dialytic) and electrocardiographic (ECG) observation of cardiac rhythm. Hemodialysis with adjusted potassium bath (high potassium bath) is being used in cardiac patients with digoxin toxicity. Vincent *et al.*, added 2.5 mEq/l of KCl in dialysate and replacement solutions in continuous arteriovenous dialysis for tumor lysis syndrome [21]. We used a similar idea for acute dialysis in critical care with serum potassium less than 3.5mg/dl. Patients in the control group were dialyzed with routine dialysate that contained a potassium bath of 2.0meq/l. The intervention group was dialyzed with a high potassium bath. Significant hypokalemia was reported in the control group (mean serum potassium 2.9 mg/dl). In the intervention group, the serum potassium level in some cases was maintained at the pre-dialysis level and was improved in other cases (mean serum potassium 4.4mg/dl). We observed life-threatening atrial fibrillation during the last hour of hemodialysis in two patients in the control group who had hemodialysis with conventional potassium bath (K bath: 2.0med/dl), hypokalemia then was subsequently confirmed in both patients by laboratory testing and both patients

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were managed by immediate discontinuation of dialytic treatment. In one patient atrial fibrillation was observed within half an hour of completion of dialytic treatment and hypokalemia was again confirmed in this case by serum testing for potassium level. This patient was managed with intravenous potassium replacement. Fortunately, all patients survived with timely appropriate action. While in the intervention group, we safely performed acute dialysis in critically ill patients with low/low normal serum potassium by adjusting the potassium bath without any complication.

CONCLUSIONS

Acute dialysis in critical care can be performed safely by adjusting the potassium bath in patients with low or low normal serum potassium.

Authors Contribution

Conceptualization: SB, SQ, IH, SK
Methodology: SB, SQ, IH, SK
Formal analysis: SB, SQ, IH, SK
Writing, review and editing: SB, SQ, IH, SK

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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