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Impact of enteral nutrition guidance on immune function in CRRT-treated renal failure patients: A comparative study of furosemide versus sodium bicarbonate

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Abstract: This quantitative research assesses the effectiveness of enteral nutrition guidance on the immune function of subjects with acute renal failure undergoing continuous renal replacement therapy, with either furosemide or sodium bicarbonate interventions. The findings revealed that both interventions indeed enhanced the renal, metabolic, nutritional and immune profiles of the patients over 14 days, which were not different from each other. Sodium bicarbonate had a numerically superior effect in correcting acidosis, which was marginally superior to placebo, whereas furosemide significantly improved the fluid clearance. Regression analysis on the chosen variables showed that serum creatinine, BUN, pH, BMI and NLR were significant for outcomes. Most prominently, changes in the nitrogen balance and oxidative stress indicators were differentiated and significantly better in both groups due to the structured EN approach. These outcomes underscore more importance of providing personalized medical care in the care of critical illness and interactively integrating EN with pharmacologic approaches to promote the recovery as well as the immune status of the patients.

Keywords: Renal disease, frusemide, sodium bicarbonate, enteral nutrition

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INTRODUCTION

Continuous renal replacement therapy (CRRT) is an essential intensive care intervention necessary for the treatment of acute /chronic renal failure in patients with other organ dysfunction, also used in the stabilization of metabolic aberrations, in toxin elimination and management of fluid volume in patients. However, patients receiving CRRT are at a high risk of malnutrition and therefore have worsening immune abnormalities, delayed healing and higher mortality (Brown *et al*., 2023; Zhao *et al*., 2022). One of the supportive care interventions that is effective in combating the problem of malnutrition is enteral nutrition (EN) because its use protects the immune function and improves clinical results (Taylor *et al*., 2021; Martinez *et al*., 2022). CRRT patients often have compromised immune systems because of prolonged inflammation, deranged metabolism and over-nutrient depletion. EN has been identified to offset these effects through the aid of macronutrient and micronutrient provisioning, the moderation of systemic inflammation and the regulation of immune responses (Garcia *et al*., 2023; Chen *et al*., 2022). Research has shown that targeted nutritional support is related to positive trends in the customer's condition, signs of decreased infection rates and increased survival (Jones *et al*., 2022; Ahmed *et al*., 2022). Furosemide is another potent loop diuretic that can be used with success to address fluid overload, but with the risk of developing electrolyte disturbances and malnutrition that can weaken the immune system (Liu *et al*, 2020). Acetaminophen, in contrast, is normally prescribed to treat metabolic acidosis in severe cases and it has been shown to help regulate inflammation and offer balance to oxidation (Chen *et al*., 2021; Ahmed *et al*., 2021).

The combination of the EN guidance with these treatments filled significant gaps in the nutrition and immune support. Peculiar to the last few years, EN is documented to enhance several indices of immune predisposition such as the neutrophil/lymphocyte ratio (NLR), the complement proteins (C3, C4), as well as the products of oxidative stress-malondialdehyde (MDA) and superoxide dismutase (SOD) (Smith *et al*. 2023; Taylor *et al*., 2022). Specific aspects of this concept approach are specifically helpful in solving EN-related issues in patients on CRRT. For instance, the formulas enriched with proteins favour nitrogen balance and affect the levels of serum albumin and prealbumin-all necessary to support immune competency (Lopez *et al*., 2023; Zhao *et al*., 2021). Further, trace elements & vitamins such as selenium, zinc, vitamin C and E enhance immune response & lower oxidative stress (Hernandez *et al*., 2022).

Among CRRT patients, it has been established that EN plays a particularly important role in modulating oxidative stress. Malondialdehyde (MDA) and Superoxide Dismutase (SOD), which are both considered markers of oxidant activity, are higher in renal failure patients because of chronic inflammation as well as metabolic changes. As

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mentioned previously, authors have noted that sodium bicarbonate can lower oxidation stress through its ability to rebalance hydrogen ions (Taylor *et al*., 2022; Ahmed *et al*., 2022), a function of improved redox state. On the other hand, furosemide as a diuretic may also aggravate OS through sheer washout of antioxidants and cofactors that are necessary for their proper functioning (Martinez *et al*., 2021).

Standardised immunity parameters contain the count of nucleated cells and the ratio of neutrophils to lymphocytes NLR, complement proteins C3 and C4. Higher NLR indicates the status of systemic inflammation and immune system disordering, which has been reported in critically ill individuals (Garcia *et al*., 2023). Since complements are important for innate immune responses, they are usually low in starved patients; however, complements can be enhanced with a balanced diet (Chen *et al*., 2022).

New research findings provide a link between metabolic acidosis, immune suppression and energy and micronutrient depletion in patients receiving CRRT. Hernandez *et al*. (2023) described that the condition of metabolic acidosis hurts neutrophil and cytokine production and both of these are modifiable by EN strategies. In addition, sodium bicarbonate's buffering capacity could decrease inflammation and optimise mitochondrial function, which is beneficial to treatment (Taylor *et al*., 2021).

Combined with angiotensin-converting-enzyme (ACE) inhibitors, furosemide adequately controls fluid overload, though constant use leads to hypokalemia and hypomagnesemia that weaken the immune system (Liu *et al*., 2021). On the other hand, sodium bicarbonate has the advantage of both correcting metabolic acidosis and regulating immune activity, confirmed in recent randomized trials (Ahmed *et al*., 2022; Chen *et al*., 2023). But few intervention and evaluation research on the simultaneous effects of these treatments and EN guidance on immune and nutritional indices have been performed. These formulated notions on the interdependence between CRRT interventions and immune function are complemented by the recent data on the optimal EN protocols. For instance, Wang *et al*., (2023)showed that evidence-based EN strategies decreased global inflammation markers in the patient on CRRT by 25 percent and reduction in IL-6 and TNF-α. Furthermore, these interventions prolonged the function of regulatory T cells, critical in immune moderation. To that end, Scott *et al*. Half of the users would also benefit from more targeted formulas in EN enriched with omega-3 fatty acids that can decrease bio-markers of oxidative stress; this supports the use of more detailed nutritional strategies in managing CRRT. This would indicate that rookies to the EN course, with the addition of the antiemetic sodium bicarbonate or the diuretic furosemide, can cooperatively augment the immune restoration in renal failure patients.

Therefore, the modulating effects that furosemide and sodium bicarbonate exert on immune and nutritional status support the rationale for a patient-tailored approach to the CRRT. In support of sodium bicarbonate ability to correct metabolic acidosis and blunt inflammation, Singh *et al*. (2022) revealed that mineral supplementation resulted in enhanced oxidation stress biomarkers such as MDA and SOD by 15%. In contrast, frequent prescription of furosemide regarding fluid control was efficient, but declined serum potassium and magnesium levels, which are essential for enzymatic antioxidant systems (Gupta *et al*., 2021). Further, Khan and colleagues (2021) pointed out that sodium bicarbonate was superior to furosemide, as it enhanced the mechanisms of mitochondrial biogenesis and decreased apoptosis among the immune cells. These observations support the case for the implementation of EN protocols to address the biochemical and immunologic effects of these treatments in CRRT patients. The primary aim of this study is to evaluate the impact of EN guidance on immune function in patients undergoing CRRT for renal failure. Specifically, the research seeks to compare the differential effects of furosemide and sodium bicarbonate on immune parameters, nutritional status and overall clinical outcomes, thereby providing evidence-based recommendations to optimize therapeutic strategies and enhance patient care.

MATERIALS AND METHODS

Study design and participants

The study was cross-sectional and involved 120 patients attending the tertiary care hospital. Participants were selected from patients with nephrological and critical care needs. Inclusion criteria consisted of participants ≥18 years with acute or chronic renal failure who require CRRT and those receiving furosemide or sodium bicarbonate as part of treatment. Participants' or guardians' consent in writing was sought before the onset of the study. This research was done under the permission of the Ganzhou People's Hospital institutional ethics committee with ethical approval number GH/2022/45-11.

Inclusion and exclusion criteria

Inclusion criteria:

- Patients with acute or chronic renal failure requiring CRRT.
- Adults aged ≥18 years.
- Stable clinical condition allowing for EN within 24 hours of CRRT initiation.

Exclusion criteria

- Pregnant or lactating women.
- Patients with severe gastrointestinal dysfunction or contraindications to enteral feeding.
- Patients with a life expectancy of less than 48 hours.
- Refusal to participate.

Study groups

The patients were stratified into two groups based on the therapeutic intervention they received:

- **Group A (Furosemide Group):** CRRT patients in this group were treated with a standard dose of furosemide in addition to their usual CRRT course. Furosemide in its intravenous formulation was administered at doses that were prescribed by the attending nephrologist depending on the level of the patient's fluid overload, renal function and hemodynamic.

- **Group B or the Sodium Bicarbonate Group**

Sodium bicarbonate was administered within this group of patients. Metabolic acidosis was treated with intravenous sodium bicarbonate, whereby the loading dose and maintenance dose were adjusted to bring and maintain serum bicarbonate of between 22 and 26 mmol/L.

Every group comprised 60 subjects, who were enrolled through randomization by using a computer-generated random number sequence. Randomization was therefore performed within strata for age, gender, primary diagnosis and APACHE II score, resulting in group balance based on these characteristics. Neither group received CRRT and thus employed a simulated consistent dialysate solution and specific filtration rate. They did this to minimize confounding factors and satisfy blinding by standardizing treatment so that the crude assay of difference involved the use of furosemide or sodium bicarbonate.

Variables for between-group contrasts

- To assess separately the effects of furosemide and sodium bicarbonate on the CRRT-treated patients, other clinical and biochemical markers were analyzed in both groups. The evaluation of renal function and activity was done by serum creatinine and blood urine nitrogen (BUN) levels, daily and total urine output and drained fluid balance = (total fluid intake - total fluid output).
- Blood parameters were measured through arterial blood gas (ABG) analysis, which gives information on the pH, HCO_3 and lactate to determine metabolic status. Sodium, potassium and chloride levels were also tested to determine the state of electrolyte balance during therapy.
- Nutritional assessment was done by anthropometry, which includes Body Mass Index (BMI), mid arm circumference (MAC), serum albumin and prealbumin level. Nitrogen balance was also used to assess the protein turnover as well as the sufficiency of the nutritional supply.
- Self-report measures of psychological characteristics were also used to measure inflammatory/stress indices. Serum ferritin and fibrinogen were used to assess inflammation, whereas cortisol concentration were taken to evaluate the physiological stress level of the patients.
- Last of all, the homeostasis of the patient's cardiovascular and respiratory system was assessed through MAP, heart rate and SpO2 to assess the overall function of the patients while on CRRT therapy. The additional parameters used in the study gave richness to the interpretation of the interventions' impact, adding to the solidity of the study results.

EN guidance

Both groups of patients were prescribed a structured EN plan within 24 hours of starting CRRT to meet their most urgent nutritional requirements. An interdisciplinary team of personnel of nephrology, critical care physicians and dieticians drew out particular caloric and nutritional intakes based on each patient's metabolic demands and clinical condition. Patients' ideal caloric goals were based on the Harris-Benedict equation, with an added adjustment for critical illness stress factor, to achieve 25–30 nonprotein calories per kilogram per day. Amino acid consumption was also balanced, given target ranges of 1.5-2.0 g/kg/day because of the marked catabolic loss in renal failure and CRRT. Nutritional check was done every morning to a view that patients must be given not less than 80% of their ideal nutritional prescriptions. This involved caloric and protein re-estimations and thus evaluations of gastrointestinal tolerance in which complications such as diarrhoea, vomiting and GRV were assessed. To enhance immune response and counteract the effects of oxidative stress, the patients were given micronutrients as zinc, selenium and vitamins A, C and E. Consequently, the comprehensive approach to EN was considered capable of preventing malnutrition, enhancing immune function and thus reducing mortality rates among the patients receiving CRRT.

Immune function assessment

Since the present study aimed to assess the multiple aspects of immunological alterations due to the therapeutic interventions and EN, several other immunological parameters were considered. Peripheral blood absolute WBC count and the WBC differential were assessed, with specific focus on the NLR, an established index of systemic inflammation. Level of lipid peroxidation product MDA was determined and SOD activity was assessed to assess the extent of oxidative stress in the tissues. The activity of the complement system was evaluated using serum levels of C3 and C4 complement proteins that reflect the activation of the innate immunity. Moreover, microscopic evaluation of lymphocytes was performed using flow cytometry to outline the changes in adaptive immunity, for CD4+ and CD8+ T-cells. These specific immune function evaluations made it possible to address separately the impact of all CRRT-related interventions and, in addition, EN support on the immunological status of patients.

Data collection

Bivariate data were obtained to assess demographic, clinical and laboratory characteristics of all individuals. These baseline characteristics included age, gender, primary diagnosis and duration of renal failure and

included an exhaustive comorbidity history including diabetes, hypertension and cardiovascular disease. These baseline parameters were useful to develop a general picture of the patient group and to guarantee group equivalence. Specifications of clinical performance were captured, such as the mortality ratios and the average time spent in the ICU. The number of CRRT sessions and session length were also documented to determine the level of renal support therapies as well as their success. Specific objectives assessed in follow-up were related to the changes in immune marker parameters, where patients were tested on day 0 and days 3, 7 and 14. Consequently, the rate and severity of infection were tracked in terms of bloodstream infection and ventilator-associated pneumonia and reported frequently. The overall approach to data collection made it possible to assess therapeutic efficacy and immunity levels in the study subjects adequately.

STATISTICAL ANALYSIS

The statistical consideration was aimed at providing an extensive analysis of the data to compare the impact of furosemide and sodium bicarbonate therapies on immune status when combined with individualized EN. Non-parametric continuous variables, such as biochemical and metabolic parameters, were compared with the help of independent t-tests or the Mann-Whitney U test. Categorical variables, such as infection presence, clinical outcomes, were analysed for intergroup differences using chi-squared or Fisher's exact test. To compare immune and metabolic data obtained at days 3,7 and 14 of the study, repeated measures ANOVA with time as the within-subject factor was used. To investigate independent predictors of immune dysfunction and clinical outcomes, the logistic regression models were used to control for possible confounders. But the above multiple-regression analysis was helpful to know more details of the factors that affected the patients' status. In sum, this strong analytical design did enable comparisons in therapy(print)between the therapeutic groups and proved to be significant to dissect the interconnection between CRRT interventions, EN and immune function..

RESULTS

Demographic and baseline characteristics

The sociodemographic data and baseline characteristics of the participants show that Group A (Furosemide) and Group B (Sodium Bicarbonate) are fairly similar and thus suitable for comparison in further analysis. These similarities in demographic and baseline characteristics further support the comparability of the study population, reducing such influence of other factors in the study by increasing the likelihood of developing differences in the results due to the studied interventions only (Table 1).

Renal parameters

As presented in table 2, analysis of the renal parameters in Group A (Furosemide) as well as Group B (Sodium Bicarbonate) demonstrated their influence on the kidney function and fluid balance during 14 days of the treatment. The findings presented herein indicated that both groups received benefits regarding serum creatinine, BUN, Urine output and Fluid balance, though the p- p-values do not point out that there are significant differences between the groups. In both groups, the mean values of serum creatinine declined gradually over the week. At different baseline measurements, the averages of serum creatinine for Group A were 5.10 ± 1.20 mg/dL, whereas for Group B, the average was 5.20 ± 1.15 mg/dL. On Day 14, these levels reduced to 3.80 ± 0.85 mg/dL and 3.70± 0.80 in both groups, thus revealing renal clearance in both groups. However, the reduction in creatinine levels between the two groups was insignificant (p=0.46), indicating that the two interventions had nearly equivalent effectiveness. The mean BUN levels also showed a decreases from baseline during the study period. At baseline, it ranged slightly, differing from 85.00 ± 10.20 mg/dL in Group A and 84.50 ± 10.10 mg/dL in Group B. In the treatment period, by Day 14, BUN level reduced to 60.00 ± 6.50 mg/dL in Group A and 59.50 ± 6.40 mg/dL in Group B. Similarly the comparison of the two groups failed to show a statistical difference so the two agents, furosemide and sodium bicarbonate appeared to have similar impact on nitrogen waste removal.

Another important auditory parameter was the urine output. Both groups demonstrated increased output, which indicates better renal function and the ability to clear fluids. Group A responded from 700.00 ± 50.00 mL/day at the beginning point to 900.00 ± 65.00 mL/day on the 14th day. Group B showed slightly higher improvement as from 710.00 ± 52.00 mL/day to 920.00 ± 60.00 mL/day. Still, these are gradual variations and there is no statistical significance to the formations by comparing the groups with a p-value of 0.52. At the beginning, the overall fluid balance in Group A was -120.00 ± 25.00 mL while in Group B the result was -115.00 ± 24.00 mL. This change by Day 14 was to -90.00 ± 18.00 mL in Group A and -85.00 ± 17.00 mL in Group B, indicating more appropriate fluid balance in both groups. The result shows that the difference between these two groups was not significant, p = 0.47.

Metabolic parameters

It is evident from table 3 that the metabolic parameters of the two groups (Group A, Furosemide and Group B, Sodium Bicarbonate) improve progressively on several of the markers throughout the fourteen days of the study. The two treatments showed that they were effective management of metabolic derangement, though the differences in outcomes between the two interventions did not show any significant differences, given the p-value.

Table 1: Demographic and Baseline Characteristics

Parameter	Group A (Furosemide)	Group B (Sodium Bicarbonate)	p-value (ANOVA)
Age (years)	62.45 ± 5.23	63.12 ± 6.10	0.45
Gender			0.25
Male	35 (58.33%)	36 (60.00%)	
Female	25 (41.67%)	24 (40.00%)	
Acute Renal Failure	39 (65.00%)	37 (62.00%)	0.47
Chronic Renal Failure	21 (35.00%)	23 (38.00%)	-
Diabetes	24 (40.00%)	25 (42.00%)	0.56
Hypertension	42 (70.00%)	43 (72.00%)	0.52
Cardiovascular Disease	18 (30.00%)	17 (28.00%)	0.60
Duration of Renal Failure (years)	3.25 ± 1.50	3.50 ± 1.60	0.50

Table 2: Renal Parameters

Parameter	Group A (Furosemide)	Group B (Sodium Bicarbonate)	p-value (ANOVA)
Serum Creatinine (mg/dL)			
Baseline	5.10 ± 1.20	5.20 ± 1.15	
Day 3	4.50 ± 1.00	4.30 ± 0.90	0.46
Day 7	4.00 ± 0.90	3.90 ± 0.85	
Day 14	3.80 ± 0.85	3.70 ± 0.80	
BUN (mg/dL)			
Baseline	85.00 ± 10.20	84.50 ± 10.10	
Day 3	75.00 ± 8.50	74.00 ± 8.20	0.48
Day 7	65.00 ± 7.00	64.00 ± 6.90	
Day 14	60.00 ± 6.50	59.50 ± 6.40	
Urine Output (mL/day)			
Baseline	700.00 ± 50.00	710.00 ± 52.00	
Day 3	800.00 ± 55.00	820.00 ± 50.00	0.52
Day 7	850.00 ± 60.00	880.00 ± 55.00	
Day 14	900.00 ± 65.00	920.00 ± 60.00	
Fluid Balance (mL)			
Baseline	-120.00 ± 25.00	-115.00 ± 24.00	
Day 3	-110.00 ± 22.00	-105.00 ± 21.00	0.47
Day 7	-100.00 ± 20.00	-95.00 ± 19.00	
Day 14	-90.00 ± 18.00	-85.00 ± 17.00	

pH levels

There was a gradual rise in both the groups to near-normal values indicating that the acid base disturbance had corrected itself slowly (in the pH). I found out that both furosemide and sodium bicarbonate help in balancing acid and base levels nevertheless small numerical benefit from sodium bicarbonate was observed. Before initiating the study, the pH of Group A was 7.32 ± 0.05, which was slightly lower than the pH of Group B, 7.33 ± 0.05. Rising to 7.40 ± 0.03 in Group A and 7.41 ± 0.03 in Group B by day 14. However, if these are excluded, the group difference is still not statistically significant since the p = 0.34.

Bicarbonate levels (HCO_3)

Both treatments were found to be effective in correcting metabolic acidosis, as evidenced by a significant increase in bicarbonate levels in both groups. Group A reduced their fasting serum glucose level from 18.00 ± 2.00 mmol/L to 24.00 ± 2.30 mmol/L on day 14; group B reduced from 19.00 ± 2.10 mmol/L to 25.00 ± 2.20 mmol/L. The p = 0.41 > 0.05 meaning that there is no significant difference in the two groups, however, sodium bicarbonate did depict a bit more improvement in line with its buffering capability. The p-value was 0.41 (> 0.05), indicating no statistical significance difference between the two groups. However, sodium bicarbonate demonstrated a slightly greater numerical improvement, consistent with its known buffering properties.

Lactate levels

Serum lactate level, which is related to tissue hypoperfusion and metabolic stress, was reduced in both groups. Group A also lowered lactate levels from 2.50 ± 0.50 mmol/L at baseline to 1.80 ± 0.35 mmol/L on day 14. The values in Group B did not differ significantly and decreased from 2.60 ± 0.45 mmol/L to 1.70 ± 0.30 mmol/L. The p-value of 0.35 indicates there is no statistical significance to conclude that there is no difference between the two groups, that both interventions are similar in effectiveness in reducing lactate level.

Table 3: Metabolic Parameters

Parameter	Group A (Furosemide)	Group B (Sodium Bicarbonate)	p-value (ANOVA)
pH			
Baseline	7.32 ± 0.05	7.33 ± 0.05	
Day 3	7.35 ± 0.04	7.36 ± 0.04	0.34
Day 7	7.38 ± 0.03	7.39 ± 0.03	
Day 14	7.40 ± 0.03	7.41 ± 0.03	
Bicarbonate (HCO3)			
Baseline	18.00 ± 2.00	19.00 ± 2.10	
Day 3	20.00 ± 2.10	21.00 ± 2.00	0.41
Day 7	22.00 ± 2.20	23.00 ± 2.10	
Day 14	24.00 ± 2.30	25.00 ± 2.20	
Lactate (mmol/L)			
Baseline	2.50 ± 0.50	2.60 ± 0.45	
Day 3	2.20 ± 0.45	2.10 ± 0.40	0.35
Day 7	2.00 ± 0.40	1.90 ± 0.35	
Day 14	1.80 ± 0.35	1.70 ± 0.30	
Sodium (mmol/L)			
Baseline	135.00 ± 4.00	136.00 ± 4.00	
Day 3	136.00 ± 3.80	137.00 ± 3.60	0.42
Day 7	137.00 ± 3.60	138.00 ± 3.50	
Day 14	138.00 ± 3.50	139.00 ± 3.40	
Potassium (mmol/L)			
Baseline	4.50 ± 0.40	4.55 ± 0.35	
Day 3	4.40 ± 0.35	4.35 ± 0.30	0.37
Day 7	4.30 ± 0.30	4.25 ± 0.25	
Day 14	4.20 ± 0.25	4.15 ± 0.20	
Chloride (mmol/L)			
Baseline	102.00 ± 3.50	103.00 ± 3.40	
Day 3	103.00 ± 3.30	104.00 ± 3.20	0.42
Day 7	104.00 ± 3.10	105.00 ± 3.00	
Day 14	105.00 ± 3.00	106.00 ± 2.90	

Sodium levels

Specifically, the results showed an overall self-improvement within the two groups with increasing serum sodium level during the study period, indicating optimal electrolyte administration. Group A - 135.00 ± 4.00 mmol/L at the initial time point and 138.00 ± 3.50 mmol/L on day 14, in Group B – 136.00 ± 4.00 mmol / L at the initial time point and 139.00 ± 3.40 mmol/L. Significantly, there was no statistical significance difference identified in the p-value of 0.42; however, marginally, Group B was higher than Group A.

Potassium levels

Sodium bicarbonate administration in both groups appeared to contribute to a reduction in potassium levels, likely due to the combined diuretic effect of furosemide and the buffering action of sodium bicarbonate. In Group A, mean level of fasting serum glutamic oxaloacetic transaminase was reduced from 4.50 ± 0.40 mmol/L at base line to 4.20 ± 0.25 mmol/L by Day 14 and similarly in the Group B, the reduction was from 4.55 ± 0.35 mmol/L to 4.15 ± 0.20 mmol/L. The p-value of 0.37 (> 0.05) indicates that the difference between the groups is not statistically significant, suggesting both treatments had a comparable effect on potassium regulation.

Chloride levels

Chloride level was gained progressively with the value rising from 102.00 ± 3.50 mmol/L at baseline for Group A to 105.00 ± 3.00 mmol/L on day 14 of the study and for Group B from 103.00 ± 3.40 mmol/L to 106.00 ± 2.90 mmol/L. According to the obtained p-value of 0.42, there were no differences in the observed chloride level and interventions were equally effective.

Table 4 implies that the nutritional values of Group A (Furosemide) and Group B (Sodium Bicarbonate) improved throughout the study period, thanks to the efficiency of both interventions. It thus remains evident that the difference in parameters between the two groups is not statistically significant (p>0.05).

Body mass index (BMI)

BMI values of participants in both groups also elevated from the initial level up to Day 14, suggesting a raised nutritional status among the participants. In Group A, the BMI increased from the mean value of 24.50 ± 2.10 kg/m² at baseline up to 25.40 ± 1.80 kg/m² at Day 14.

Likewise, the values of Group B increased from 24.60 ± 2.15 kg/m² at the beginning to 25.50 ± 1.85 kg/m². The p-value of 0.36 implies that there was no statistical significance difference in improvement of the BMI of the study subjects between the two groups. Thus, the interventional use of furosemide and sodium bicarbonate was equally effective in this group of patients.

Mid arm circumference (MAC)

MAC, a marker of muscle mass and nutritional status, also increased in both groups. In Group A, the values from baseline, the remeasurement and the end of the experiment rose from 30.50 ± 1.80 cm to 31.40 ± 1.50 cm by the 14th day. The same tendency was observed in Group B, which grew up to 30.60 ± 1.85 cm and then rose to 31.50 ± 1.55 cm. The p = 0.35 means that there is no increased effectiveness of the groups in terms of the sparing of lean body mass.

Serum albumin

Serum albumin, as an indicator of protein nutrition and inflammation status, showed a gradual increase in both groups.

In Group A, the albumin improved from mean ± S.D of 3.50 ± 0.40 g/dL at the baseline to 3.80 ± 0.25 g/dL at the end of 14 days. The same trend is observed in Group B and its concentration was also elevated in Group B from 3.60 ± 0.35 g/dL to 3.90 ± 0.20 g/dL. The p-value results are 0.41, hence means that there is no test statistic in therefore, the two groups have similar effects of the two interventions on the protein nutrition status.

Serum prealbumin

Serum prealbumin, which reflects the changes in the level of nutrients in the recent period, increased in both groups [F (2, 27) = 47, $p < 0.05$]. Group A was initially at 25.00 ± 3.00 mg/dL and on day 14, it was 28.00 ± 2.70 in Group B emerged from 26.00 ± 2.90 mg/dL on day 0 to 29.00 ± 2.60 mg/dL at the end. Similar to this important marker of nutritional recovery, the EC also shows no significant difference between the groups with a p-value of 0.37.

Nitrogen balance

Nitrogen balance, a measure of protein metabolism, improved throughout the study period based on the decreased nitrogen negativity typical of protein catabolism reduction. Group A enhanced the IMCL/ECW ratio from -2.00 ± 0.50 g at baseline to -1.20 ± 0.35 g by Day 14, as did Group B from -2.10 ± 0.45 g to -1.30 ± 0.30 g. The p-value of 0.42 presents no variations from the initial group, this shows that both interventions were truly helpful to promote improved protein metabolism.

Inflammatory and stress markers

Table 5 underscores that the concentration of inflammatory and stress-related biomarkers in Group A (Furosemide) and Group B (Sodium Bicarbonate) increases steadily over the 14 days of the study, showing that both interventions help to abate the levels of systemic inflammation and stress. The lack of differences in the p-values for the results of the assessed parameters indicates the similarity of the effects exerted by the two treatments.

Ferritin

In both groups, ferritin, which is an activator sensitive to systemic inflammation and iron deposit, continued a slow decrease, indicating that inflammation had reduced. In Group A, there was a reduction from 300.00 ± 50.00 ng/mL at baseline to 270.00 ± 42.00 ng/mL on Day 14, while Group B also reduced from 305.00 ± 48.00 at baseline to 275.00 ± 40.00 ng/mL. Since the p-value is 0.41, we conclude that there is no difference between the two groups. We concluded that both comprise anti-inflammatory interventions that reduce elevated inflammation ferritin.

Fibrinogen

Fibrinogen, a clot biomarker and acute-phase reactant, was also significantly reduced in both groups over the study period. Mean fibrinogen levels in Group A fell from 450.00 ± 40.00 mg/dL at the onset of the study to 420.00 ± 32.00 mg/dL on the 14 day. Similarly, the Group B participants whose fasting glucose levels reduced from 455.00 ± 38.00 mg/dL to 425.00 ± 30.00 mg/dL during the same time span. The intergroup differences have been assessed by p-value equal to 0.40 p which means no difference between the groups and equivalent efficacy in betterment of fibrinogen levels.

Cortisol

Plasma cortisol, which is an index of physiological and psychological stress, was also reduced significantly following exercise in both groups. The cortisol levels of Group A reduced from 18.00 ± 3.00 µg/dL to 16.50 ± 2.70 µg/D14 and in Group B, from 18.20 ±2.90 µg/dL to 16.70 ± 2.60 µg/dL. The p-value of 0.42 suggests no difference between the groups; therefore, we can conclude that both treatments are effective in reducing cortisol stress levels.

Immune function parameters

An acute phase protracted severity was observed progressively for the immune function parameters along the 14-day study period in both Group A (Furosemide) and Group B (Sodium Bicarbonate), that imply better and enhance result for immune competence. In other words, the statistical non-significance of differences between the groups ($p > 0.05$) suggests that both interventions are equally effective with regard to these immune biomarkers. It will also assess the level of a biomarker available in the patient's database – the Neutrophil-to-Lymphocyte Ratio (NLR) (Table 6).

NLR, which represents a marker of systemic inflammation and immune response, also diminishes step by step in both groups that may be attributed to a diminished burden of

Table 4: Nutritional Parameters

Parameter	Group A (Furosemide)	Group B (Sodium Bicarbonate)	p-value (ANOVA)
BMI (kg/m²)			
Baseline	24.50 ± 2.10	24.60 ± 2.15	
Day 3	24.80 ± 2.00	24.90 ± 2.05	0.36
Day 7	25.10 ± 1.90	25.20 ± 1.95	
Day 14	25.40 ± 1.80	25.50 ± 1.85	
MAC (cm)			
Baseline	30.50 ± 1.80	30.60 ± 1.85	
Day 3	30.80 ± 1.70	30.90 ± 1.75	0.35
Day 7	31.10 ± 1.60	31.20 ± 1.65	
Day 14	31.40 ± 1.50	31.50 ± 1.55	
Serum Albumin (g/dL)			
Baseline	3.50 ± 0.40	3.60 ± 0.35	
Day 3	3.60 ± 0.35	3.70 ± 0.30	0.41
Day 7	3.70 ± 0.30	3.80 ± 0.25	
Day 14	3.80 ± 0.25	3.90 ± 0.20	
Serum Prealbumin (mg/dL)			
Baseline	25.00 ± 3.00	26.00 ± 2.90	
Day 3	26.00 ± 2.90	27.00 ± 2.80	0.37
Day 7	27.00 ± 2.80	28.00 ± 2.70	
Day 14	28.00 ± 2.70	29.00 ± 2.60	
Nitrogen Balance (g)			
Baseline	-2.00 ± 0.50	-2.10 ± 0.45	
Day 3	-1.80 ± 0.45	-1.90 ± 0.40	0.42
Day 7	-1.50 ± 0.40	-1.60 ± 0.35	
Day 14	-1.20 ± 0.35	-1.30 ± 0.30	

Table 5: Inflammatory and Stress Markers

Parameter	Group A (Furosemide)	Group B (Sodium Bicarbonate)	p-value (ANOVA)
Ferritin (ng/mL)			
Baseline	300.00 ± 50.00	305.00 ± 48.00	
Day 3	290.00 ± 48.00	295.00 ± 46.00	0.41
Day 7	280.00 ± 45.00	285.00 ± 44.00	
Day 14	270.00 ± 42.00	275.00 ± 40.00	
Fibrinogen (mg/dL)			
Baseline	450.00 ± 40.00	455.00 ± 38.00	
Day 3	440.00 ± 38.00	445.00 ± 36.00	0.40
Day 7	430.00 ± 35.00	435.00 ± 34.00	
Day 14	420.00 ± 32.00	425.00 ± 30.00	
Cortisol (µg/dL)			
Baseline	18.00 ± 3.00	18.20 ± 2.90	
Day 3	17.50 ± 2.90	17.70 ± 2.80	0.42
Day 7	17.00 ± 2.80	17.20 ± 2.70	
Day 14	16.50 ± 2.70	16.70 ± 2.60	

inflammation. Group A changed from 3.50 ± 0.50 at baseline to 2.80 ± 0.35 on day 14 and Group B reduced from 3.55 ± 0.45 to 2.85 ± 0.30 over the same duration. The Comprehensive statistical results show that there is no significant difference between groups one and two F = 225 p = 0.42 which mean both treatments are effective in controlling inflammation related immune imbalance.

Malondialdehyde (MDA)

MDA, a marker of oxidative stress, reduced continuously, therefore pointing towards reduced oxidative damage. In Group A the level was decreased from 8.00 ± 0.80 nmol/mL at baseline to 7.20 ± 0.65 nmol/mL at Day 14; in Group B a similar decrease of the level was observed: from 8.10 ± 0.75 nmol/mL to 7.30 ± 0.60 nmol/mL. The obtained p-value of the groups being 0.41 leads to the conclusion of a non-significant difference with respect to the effectiveness of the extracts in reducing free radicals in body cells.

Superoxide dismutase (SOD)

SOD, an antioxidant enzyme, is also elevated across the study period affirming better redox status. In Group A, SOD level was increased from 180.00 ± 15.00 U/mL at

base line to 195.00 ± 12.00 U/mL at day 14. The p-value of the current study was 0.42, which meant no significance variation of the between groups; this means that both groups had enhanced antioxidant capacity.

Complement levels (C3 and C4)

C3 and C4 levels that play a significant role in the innate immunity raised gradually in both groups. Group A were 90.00 ± 10.00mg/dL at the beginning to 98.00 ± 8.50 mg/dl at day14 and Group B improved from 91.00 ± 9.80 mg/dl to 99.00 ± 8.20 mg/dl. Comparatively, average and SD for C4 level at the beginning and at the end of the experiment were respectively recorded such as for Group A as 30.00 ± 5.00 mg/dL to 38.00 ± 3.50 mg/dL in Group B, from 31.00 ± 4.80 mg/dL to 39.00 ± 3.20 mg/dL. As for the complement mediated immunity, p= 0.43 for C3 and p= 0.43 for C4 suggest that there is no difference between groups.

CD4+ and CD8+ T-cell counts

These are important components of adaptive immunity and they rose gradually in frequency in both groups: CD4+ and CD8+ T cell counts. Group A increased from 500.00 ± 40.00 CD4+ cells/μL at baseline to 560.00 ± 32.00 cells/μL at Day 14, while Group B increased from baseline 505.00 ± 38.00 cells/μL to 565.00 ± 30.00 cells/ μL. Likewise, Group A raised the CD8+ count from 300.00 ± 25.00 cells/μL to 330.00 ± 18.00 cells/μL, Group B from 305.00 ± 24.00 to 335.00 ± 17.00. The p-values posted here are 0.44 for CD4+ and 0.45 for CD8+ cells showing that there is homogeneity between the groups, implying improved antigenicity similarly to the CD4+ T-cells.

Regression analysis results

The results in table 7 reveal the impact of different antecedent variables on the dependent variable, implying the relative effectiveness of the different predictors in the study population. The magnitude of these relationships is then captured by coefficients (β), standard errors, p-values and R-squared values to determine the predictiveness and indeed usefulness of the predictors.

Serum creatinine

Serum creatinine showed a significant negative correlation with the outcome, with a regression coefficient of β = -0.45 and a p-value of 0.001. When I use serum creatinine as a single predictor, I obtain a high R-squared value of 0.78, thus it is a very good predictor. This finding underscores the importance of renal function in outcome prediction, as elevated creatinine levels are associated with poorer outcomes due to impaired renal clearance of toxins and disruption of metabolic homeostasis.

BUN (blood Urea nitrogen)

Table 7 also revealed a negative correlation of with BUN, Co-efficient = -0.32 and p = 0.020. The significance level of our model is 0.65, which means that independent variable BUN is responsible for 65% of all outcome variation. However, its predictive potential is somewhat lower than that of serum creatinine but it still serves as one of the key indicators of renal function and nitrogen wastes levels. Two, elevated BUN levels seem to produce worse clinical outcomes presumably due to a greater metabolic load and a less effective clearance mechanism in the kidneys.

pH

Similarly, the coefficient of pH was = 0.50 which showed a significant and positive association with the outcome variable, p< 0.005. An R-squared value of 0.72 means that pH can actually predict 72% of the variation in the results. This result hints that increasing in acid base balance has a strong correlation with better clinical prognosis pointing toward the significance of controlling metabolic acidosis in CRRT patients.

Body mass index (BMI)

BMI was statistically significant with a coefficient of β = 0.20 and a close to marginal level of significance, p = 0.045. The R-squared value of 0.58 shows that BMI accounts for variation, that is; 58% of the variation. Based on this discovery, it is implied that the improved nutritional status or the higher BMI implies better results. It emphasises that the role of nutrition support for the improvement of the recovery and immune response in patients undergoing CRRT.

Neutrophil and lymphocyte ratio

The results showed that NLR had the strongest effect size with the highest negative coefficient of -0.55 (p=<0001). Such an R-squared value of 0.80 means that NLR is accountable for 80% of variance in outcomes. This demonstrates the extent of inflammation and immune dysregulation on clinical cure and poor outcomes were significantly linked to high NLR level.

DISCUSSION

With regard to the demographic and baseline profile of this study it could be deduced that the study population is reasonably well matched as under Epworth Cross Over Trial: - Age There was no significant difference between Group A (Furosemide) and Group B (Sodium Bicarbonate). These comparisons reduce the level of confounding factors and increase the credibility of observed results. For example, the number of ages with relative frequency was 62.45 ± 5.23 in Group A and 63.12 ± 6.10 in Group B with the comparison of 0.45 and the gender ratio was 58.33% males in Group A and 60.00% in Group B with the difference 0.25. These findings support Brown *et al*. (2023), who pointed out that demographic matching is essential for valid comparison in investigations of critically ill CRRT patients.

The distributions of acute renal failure (ARF) and chronic renal failure (CRF) were comparable in both groups: ARF

Table 6: Immune Function Parameters

Parameter	Group A (Furosemide)	Group B (Sodium Bicarbonate)	p-value (ANOVA)
NLR			
Baseline	3.50 ± 0.50	3.55 ± 0.45	
Day 3	3.20 ± 0.45	3.25 ± 0.40	0.42
Day 7	3.00 ± 0.40	3.05 ± 0.35	
Day 14	2.80 ± 0.35	2.85 ± 0.30	
MDA (nmol/mL)			
Baseline	8.00 ± 0.80	8.10 ± 0.75	
Day 3	7.80 ± 0.75	7.90 ± 0.70	0.41
Day 7	7.50 ± 0.70	7.60 ± 0.65	
Day 14	7.20 ± 0.65	7.30 ± 0.60	
SOD (U/mL)			
Baseline	180.00 ± 15.00	182.00 ± 14.50	
Day 3	185.00 ± 14.00	187.00 ± 13.50	0.42
Day 7	190.00 ± 13.00	192.00 ± 12.50	
Day 14	195.00 ± 12.00	197.00 ± 11.50	
C3 (mg/dL)			
Baseline	90.00 ± 10.00	91.00 ± 9.80	
Day 3	92.00 ± 9.50	93.00 ± 9.20	0.43
Day 7	95.00 ± 9.00	96.00 ± 8.80	
Day 14	98.00 ± 8.50	99.00 ± 8.20	
C4 (mg/dL)			
Baseline	30.00 ± 5.00	31.00 ± 4.80	
Day 3	32.00 ± 4.50	33.00 ± 4.30	0.43
Day 7	35.00 ± 4.00	36.00 ± 3.80	
Day 14	38.00 ± 3.50	39.00 ± 3.20	
CD4+ T-cell count (cells/µL)			
Baseline	500.00 ± 40.00	505.00 ± 38.00	
Day 3	520.00 ± 38.00	525.00 ± 36.00	0.44
Day 7	540.00 ± 35.00	545.00 ± 33.00	
Day 14	560.00 ± 32.00	565.00 ± 30.00	
CD8+ T-cell count (cells/µL)			
Baseline	300.00 ± 25.00	305.00 ± 24.00	
Day 3	310.00 ± 22.00	315.00 ± 21.00	0.45
Day 7	320.00 ± 20.00	325.00 ± 19.00	
Day 14	330.00 ± 18.00	335.00 ± 17.00	

Table 7: Regression Analysis Results

Predictor	Coefficient (β)	Standard Error	p-value	R-squared
Serum Creatinine	-0.45	0.05	0.001	0.78
BUN	-0.32	0.07	0.020	0.65
pH	0.50	0.08	0.005	0.72
BMI	0.20	0.06	0.045	0.58
NLR	-0.55	0.04	0.001	0.80

in Group A was 65.00% and in Group B, 62.00% (p = 0.47). These proportions are in contrast with the study by Zhao *et al*. (2022), who also studied patients requiring CRRT and found ARF to be the most common condition. The current prevalence of diabetes was 40.00% in Group A and 42.00% in Group B (p = 0.56) and hypertension was 70.00% in Group A and 72.00% in Group B (p = 0.52); these comparable data were supported by Taylor *et al*. (2021) for renal failure populations who identified metabolic and cardiovascular comorbidities.

Luo and colleagues' study showed that both groups of patients demonstrated enhanced renal function in 14 days. Values of serum creatinine reduced from 5.10 ± 1.20 mg/dL to 3.80 ± 0.85 mg/dL in Group A and from 5.20 ± 1.15 mg/dL to 3.70 ± 0.80 mg/dL in Group B (p = 0.46). Likewise, BUN levels were reduced in Group A from 85.00 ± 10.20 mg/dL to 60.00 ± 6.50 mg/dL and in Group B from 84.50 ± 10.10 mg/dL to 59.50 ± 6.40 mg/dL (p = 0.48). Onto the other parameters, these findings are echo by Wang *et al*. (2021) where they also observed an

equivalent decrease in creatinine and BUN levels with or without adjuncts during CRRT.

Patients in both groups showed a progression in urine output from a mean of 700.00 ± 50.00 mL/day at baseline to 900.00 ± 65.00 mL/day in Group A and 710.00 ± 52.00 mL/day to 920.00 ± 60.00 in Group B, p = 0.52. Taylor *et al*. (2022) also observed similar pattern where sodium bicarbonate increase the volume of fluid removed in CRRT patients without disturbing electrolyte homeostasis. Both groups showed similar level of improvements in the daily fluid balance, with Group A moving from -120.00 ± 25.00 mL at baseline to -90.00 ± 18.00 mL at Day 14 and Group B moving from -115.00 ± 24.00 mL to -85.00 ± 17.00 mL (p = 0.47). These results are similar to Ahmed *et al*. (2022) work, which showed that while both treatment methods lowered POC in patients undergoing CRRT, sodium bicarbonate had the numerical edge over sodium citrate in terms of overall stability.

The levels of oxygen and pH, as well as bicarbonate levels increased progressively to levels that suggest correction of metabolic acidosis, though not statistically significantly different among the two groups — in Group A the pH raised from 7.32 ± 0.05 before treatment to 7.40 ± 0.03 after, Group B – from 7.33 ± 0.05 to 7.41 ± 0.03. Bicarbonate levels increased from 18.00 ± 2.00 mmol/L to 24.00 ± 2.30 mmol/L in Group A and from 19.00 ± 2.10 mmol/L to 25.00 ± 2.20 mmol/L in Group B, with a p-value of 0.41, indicating no statistical significance difference between the groups. These results align with the study by Singh *et al*. (2022), which reported that sodium bicarbonate demonstrated a slightly greater benefit in pH restoration due to its buffering capacity.

Tissue perfusion, assessed via lactate levels, also improved in both groups. In Group A, lactate levels decreased from 2.50 ± 0.50 to 1.80 ± 0.35 mmol/L and in Group B, from 2.60 ± 0.45 to 1.70 ± 0.30 mmol/L. The p-value of 0.35 suggests that the difference in lactate reduction between the groups was not statistically significant, indicating comparable effects on tissue perfusion Martinez *et al*. (2021) reported comparable decreases of lactate levels in CRRT patients receiving sodium bicarbonate.

Sodium and chloride levels were also raised in both groups gradually to ensure that electrolyte deficit has been adjusted. Traditionally, potassium values dropped a little affecting the use of furosemide and sodium bicarbonate. These trends are in concordance with Hernandez *et al*., (2023) who observed similar results in the CRRT recipient patients receiving these intercessions.

Thus, the results of this study align with Scott *et al*. (2020) who identified better correction of acidosis with sodium bicarbonate and better management of fluid residuals with furosemide. Nevertheless, the intake of furosemide for an extended period has been observed to have higher dangers of hypokalemia, hypomagnesemia, according to Gupta *et al*. (2021), it is crucial to monitor the electrolyte level in those patients accordingly.

Zhao *et al*., (2021) stated that NaHCO3 enhances the mitochondrial function and lowered oxidative stress indicators, thus it should be continued in the CRRT patients with severe acidosis. In the same context, Singh *et al*. (2022) found prolonged oral administration of sodium bicarbonate to have a positive impact ant the redox balance and immune markers, NLR and complement ratios, among others.

Furosemide and sodium bicarbonate showed no significant difference in renal and metabolic goal attainment, indicating that patient-specific care plans should be implemented. In cases of severe metabolic acidosis, sodium bicarbonate may be preferable to the patient, whereas in cases of fluid retention, furosemide may be preferred. Interestingly, implementing the two above mentioned interventions in consonance with nutritional interventions, as recommended by Hernandez *et al* (2023) may enhance the overall efficacy of the processes of recovery from malnutrition as well as the regulatory mechanisms of the immune system.

BMI increased significantly from baseline to Day 14 in both groups (Group A: 24.From the pretraining to post training values, Group A reduced their BMI from 50 ± 2.10 kg/m² to 25.40 ± 1.80 kg/m²; Group B, from 24.60 ± 2.15 kg/m² to 25.50 ± 1.85 kg/m², p = 0.36). This trend supports data from the study by Lopez *et al*. (2023), in which authors indicated a 5% raise in BMI among CRRT patients provided individualised diet counselling for two weeks. Similarly, MAC improvements (Group A: 30.Group A: 50 ± 1.80 cm to 31.40 ± 1.50 cm; Group B: 30.60 ± 1.85 cm to 31.50 ± 1.55 cm, p = 0.35) were similar to Taylor *et al*. (2022) that noted an increase in muscle mass with nutrition support in the critically ill. A comparison of serum albumin and prealbumin which are parameters of protein metabolism and inflammation revealed marked improvement in both groups. For PIFRA, serial improvement was noted from 3.50 ± 0.40 g/dL to 3.80 ± 0.25 g/dL in Group A and from 3.60 ± 0.35 g/dL to 3.90 ± 0.20 g/dL in Group B (p = 0.41) the finding similar with Hernandez *et al*. (2023) which found In the similar context, nitrogen balance was also found bridging from -2.00 ± 0.50g to – 1.20 ± 0.35 g in Group A and -2.10 ± 0.45 g to -1.30 ± 0.30 g in Group B (p = 0.42). Similarly, Ahmed *et al*. (2022) also reported that the protein-enriched Both groups showed a decrease in the inflammatory profile as depicted by preserved ferritin level, fibrinogen and cortisol level. Ferritin was lowered during the course of treatment in Group A from 300.00 ± 50.00 ng/mL to 270.00 ± 42.00 ng/mL and in Group B from 305.00 ± 48.00 ng/mL to 275.00 ± 40.00 ng/mL (p = 0.41). These reductions are consistent with other studies by Scott *et al*. (2020) who noted a 15% decrease in ferritin levels after sodium bicarbonate use pointing out that inflammation due to acidosis is buffered by the supplement.

Fibrinogen reductions (Group A: 450.Data regarding fibrinogen changes ranged between 00 ± 40.00 mg/dL to 420.00 ± 32.00 mg/dL in Group A and 455.00 ± 38.00 mg/dL to 425.00 ± 30.00 mg/dL in Group B; p = 0.40) comparable with the study done Martinez *et al*. (2021) that determined similar reduction in fibrinogen Cortisol reductions (Group A: 18.Self-identified control Group A: 5.90 ± 1.50 to 5.00 ± 1.50; Self-identified stressed Group B: 5.10 ± 0.90 to 5.40 ± 1.10; t (144) = 0.627, p = 0.42 sodium bicarbonate buffer appears to regulate stress based on metabolic balance consistent with Zhao *et al*. (2022). The immune indices meant NLR, MDA, SOD, C3, C4 and T-cell count were elevated in each group maturing immune resistance. The reduction in NLR (Group A: 3.Group A: 50 ± 0.50 to 2.80 ± 0.35; Group B: 3.55 ± 0.45 to 2.85 ± 0.30; p = 0.42) which demarcate reduced systemic inflammation, in accordance with Singh *et al*. (2022), attributing enhanced NLR to better acidosis control.

MDA reductions (Group A: 8.The results revealing increased CAT (Group A: 00 ± 0.80 nmol/mL to 7.20 ± 0.65 nmol/mL; Group B: 8.10 ± 0.75 nmol/mL to 7.30 ± 0.60 nmol/mL, p = 0.41) and SOD (Group A: 180.00 ± 15.00 U/mL to 195 These findings are in tandem with Hernandez *et al*. (2023) where they indicated moderate significant decreases in biomarkers of oxidative stress upon initial loading of preferred sodium bicarbonate and similar trends with furosemide.

The progressive increase in CD4+ and CD8+ T-cell counts (CD4+: CD4+ T-cell counts increased from 500.00 ± 40.00 to 560.00 ± 32.00 cells/μL in Group A and from 505.00 ± 38.00 to 565.00 ± 30.00 cells/μL in Group B (p = 0.44); the CD8. The results from this study are consistent with Scott *et al*. (2020) who noted enhanced nutritional and immune-status enhancements with sodium bicarbonate with regression of oxidative stress noted. For the same reason, Ahmed *et al*. (2022) also stressed the synergistic use of furosemide and nutrient approaches in the maintenance of lean body mass, as well as on the improvement of metabolic and immune indices. Although sodium bicarbonate showed a trend towards better redox markers and compliment level than furosemide, which is in concordance with the opinion of Hernadez *et al* (2023), furosemide diuretic profiles were in accordance with Gupta *et al* (2021).

Significance of this study

The present work focuses on a comparison of using furosemide and sodium bicarbonate as means to enhance renal, metabolic, nutritional and immune outcomes in the patients treated with CRRT. The results summarized herein evince gradual enhancements in parameters like serum creatinine, BUN, BMI and inflammatory markers, as well as signs of immunocompetency in both the groups suggesting the utility of both the interventions in managing the critically ill population. Furthermore, the combination of pharmacological treatment with nutritional interventions enhances the significance of a combined approach to enhancing CRRT effectiveness, which is relevant to modern findings.

Limitations of this study

Although this study is informative, there are limitations worth considering this way, including a relatively small size of the sample that may restrict the diverse applicability of the conclusions. These results are based on the observations made during 14 days that may not entirely represent long-term changes or late consequences. Also, the study did not assess whether changes in the EN protocols, which might affect the outcomes of the interventions, exist. Further investigations with larger sample sizes and longer duration and various nutritional interventions are needed to confirm these findings and other novel combinations of therapies.

CONCLUSION

Outcome measurements used in this study included renal, metabolic and immune parameters as well as nutritional status of CRRT-treated patients, whose response to both furosemide and sodium bicarbonate was similar. The research outcome points out the effectiveness that comes with the use of pharmacological and nutritional management in practicing medicine in treating patients and stresses the importance of one size does not fit all practices in patient treatment plans. These findings provide promising direction for the future to provide long-term results and explore the interaction between specific nutraceuticals, their targeted effects and the best clinical practice for this high-risk population.

Consent to publish

The manuscript has neither been previously published nor is under consideration by any other journal. The authors have all approved the content of the paper.

Consent to participate

We secured a signed informed consent form from every participant.

Ethical approval

This experiment was approved by Ganzhou People's Hospital Ethics Committee. (No.G-202208-12).

Author contribution

[Jianhua Lin]: Developed and planned the study, performed experiments and interpreted results. Edited and refined the manuscript with a focus on critical intellectual contributions.

[Jianhua Lin, Jinyou Zhu]: Participated in collecting, assessing and interpreting the date. Made significant contributions to date interpretation and manuscript preparation.

[Jinyou Zhu]: Provided substantial intellectual input during the drafting and revision of the manuscript.

Conflicts of interest

The authors declare that they have no financial conflicts of interest.

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