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Treatment of Metabolic Acidosis in Altering Inflammatory Biomarkers in Renal Transplant Recipients; A Randomized Clinical Trial

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Abstract

Background: Metabolic acidosis following kidney transplantation can lead to several undesirable effects such as disturbing the protein balance resulting in a negative nitrogen equilibrium, increased protein degradation, and essential amino acid oxidation.
Objectives: The current study aimed tocompare the effect of normal saline as a common crystalloid in kidney transplant surgery to reduce the risk of hyperkalemia and sodium bicarbonate on the metabolic acidosis rate after renal transplantation.
Methods: A total of 40 patients with end-stage renal disease (ESRD) and candidates receiving renal transplant from a living donor referring to the kidney transplantation department of a University affiliated hospital, Tehran, Iran, that meeting the inclusion criteria of this study, were randomly assigned to the intervention group, who were treated with sodium bicarbonate, and the control group, who were treated with normal saline. The primary outcomes measured in this study were acidosis biomarkers including BE, HCO_3, $PaCO_2$, and PH and the secondary outcomes included some inflammatory biomarkers and some renal function biomarkers.
Results: The mean ± standard deviation of age in the intervention and control groups was 44.4 ± 12.4 and 40.0 ± 13.0, respectively (P = 0.01). A total of 29 of the participants were male (14 in the intervention group and 15 in the control group), and 11 of them (six in the intervention group and five in the control group) were female. The mean ± standard deviation of change in the concentration of PH, BE, HCO_3, and $PaCO_2$ in the intervention and control groups was 0.01 ± 0.1 and -0.08 ± 0.1 (P < 0.001); 0.61 ± 4.2 and -3.8 ± 2.6 (P < 0.001); 0.36 ± 2.9 and -2.67 ± 2.1 (P: 0.001); and 0.8 ± 5.4 and 1.4 ± 5.3 (P: 0.799), respectively.
Conclusions: The present study revealed that the patients who received sodium bicarbonate had a better status than the normal saline recipients in terms of the maintenance of acid-base homeostasis, inflammatory indexes, and renal function.

Keywords: Acidosis, End-Stage Renal Disease, Failure, Hyperkalemia, Inflammatory Biomarkers, Kidney, Metabolic Acidosis, Transplantation

1. Background

End-stage renal disease (ESRD) is one of the major causes of mortality and morbidity worldwide (1). The prevalence of this disorder in the United States and the European Union is 1500 and 800 per million population (pmp), in developing countries it varies from less than 100 pmp in sub-Saharan Africa and India, 330 pmp in Jordan, 360 pmp in Iran, and 600 pmp in Saudi Arabia (2-4). ESRD patients are dependent on renal replacement therapy for survival. At the end of 2005, 1,900,000 patients with ESRD around the world had undergone renal replacement therapy, while 68% of them were undergoing hemodialysis, 8% undergoing peritoneal dialysis, and 23% undergoing kidney transplantation surgery (5). In Iran, 52.7% of patients undergo hemodialysis, 45.5% of them undergo kidney transplantation surgery, and less than 1% undergo peritoneal dialysis (6, 7).

Since renal transplantation, in comparison with dialysis, has significantly improved the quality of life and has a more acceptable cost-effectiveness ratio (8), patients often prefer to benefit from this operation to maintain their lives (9). However, evidence suggests an increase in the prevalence of metabolic acidosis following kidney transplantation (10, 11). Although metabolic acidosis is one of the most common disorders in ESRD patients due to the inability to excrete nonvolatile acid confronting a reduction in renal bicarbonate synthesis in patients with renal failure (12), after kidney transplantation, there is the probability of acidosis due to several factors such as the loss

of the nephron mass, which leads to disturbances in renal acid handling, the use of immunosuppressive drugs, and defective ammonia synthesis because of insulin resistance (13). Metabolic acidosis following kidney transplantation can lead to several undesirable effects such as disturbing the protein balance resulting in a negative nitrogen equilibrium, increased protein degradation and essential amino acid oxidation, decreased leptin, increased corticosteroid production and PTH (14), reduced physical functioning and consequently decreased quality of life and anxiety and depression, cardiovascular problems (15), and even reduced bone density (16).

2. Objectives

Considering the many complications of acidosis, the correction of acid-base balance and the correction of acidosis after kidney transplantation can be of particular importance. In this randomized clinical trial, it was tried to compare the effects of normal saline, as a crystalloid commonly used in kidney transplantation to reduce the risk of hyperkalemia and sodium bicarbonate on the metabolic acidosis rate after renal transplantation.

3. Methods

This study was performed as a randomized clinical trial with a parallel design and per protocol analysis in which the participants were allocated to the intervention group and the placebo group at 1:1 ratio (IRCT2015092712203N4). The population under study included all individuals with end-stage renal disease and candidates receiving renal transplant from a living donor who referred to the kidney transplantation department of Shahid Modarress Educational Hospital (The only governmental facility in northwestern Tehran, Iran) from April 2016 to February 2017. In brief, a total of 57 individuals with age $\geq$ 18 years, who participated in our study, were selected as baseline population. Among these participants, we excluded those with (a) advanced cardiovascular diseases (n = 5), (b) metabolic acidosis with PH less than 7.15 (n = 2), (c) operation duration of more than 3-hours (n = 1), (d) body temperature before or during operation less than 35°C axillary or more than 38.5°C axillary, (e) needing blood transfusion during the surgery (n = 4), (f) over 70 or under 18 years of age (n = 2), (g) receiving renal transplant from a deceased donor, and (h) a history of tumor and immunological diseases and taking immunomodulator drugs (n = 3). Informed consent was obtained from all individual participants included in the study.

The inclusion criteria were the ASA Class I-II andthe ages between 18 and 70 years old. The patients were randomly assigned to the intervention (i.e., sodium bicarbonate-treated) group and the control (i.e., normal saline treated) group. The random allocation of individuals to the intervention and control groups was performed using the balanced block randomization technique. Considering that in this study they were divided into blocks of four, Stata software was used to produce random number chains to reach the desired sample size. Given that the total number of states for two individuals to be in blocks of four was six, if the generated number was greater than six, then the next number would be generated regardless of the number. The preparation of random allocation sequences of individuals and putting them in sealed envelopes numbered with a 5-digit serial number were done by a third person who was not involved in designing the study. Immediately after completing the basic information and experiments of each person, an envelope containing a randomized 5-digit serial number was opened and the person was assigned to either the intervention (sodium bicarbonate treated) or the placebo (normal saline treated) groups. The primary consequences of the study were acidosis biomarkers including BE, HCO_3, PCO_2, and PH and the secondary consequences measured included biomarkers related to the consequence of renal transplant patients including IL-2, IL-10, IFN-γ, BUN, Urine Volume, and Cr of serum. At first, before the anesthetic induction, a catheter No. 18 was used for administering fluids and medicine to the patient. An invasive blood pressure monitor was performed by local anesthesia after an Allen test, through an arterial catheter No. 20 in the radial artery of the non-dominant hand. The same catheter was used to collect the arterial blood sample at the beginning of the operation and during opening the clamp. Patients were preoxygenated with 100% oxygen for three minutes and then, based on a medical indication, midazolam (0.20 mg /kg) and fentanyl (2 μ/Kg) were applied. For anesthetic induction, 5 mg/kg thiopental sodium and for muscle relaxation 0.5 mg/kg atracurium were slowly administered. To maintain anesthesia, Isoflurane (0.6% - 1%) along with nitrous oxide were used with an equal proportion. During the operation, and if necessary, supplementary doses of Atracurium were used. It should be noted that the last dose of Atracurium was prescribed during opening the clamp. After the induction, a CV line was inserted through the right jugular vein for the patient. During the operation, central venous pressure (CVP) was maintained between 10 - 12 cmH_2O and the patient's temperature was maintained at 36°C. For the patients in both groups, 3 mg/kg of intravenous Lasix and 0.5 g/kg of intravenous Mannitol were administered. During this process, none of the participants that entered the study needed blood infusion. In addition, in all kidney donors, 50 mL/kg of normal

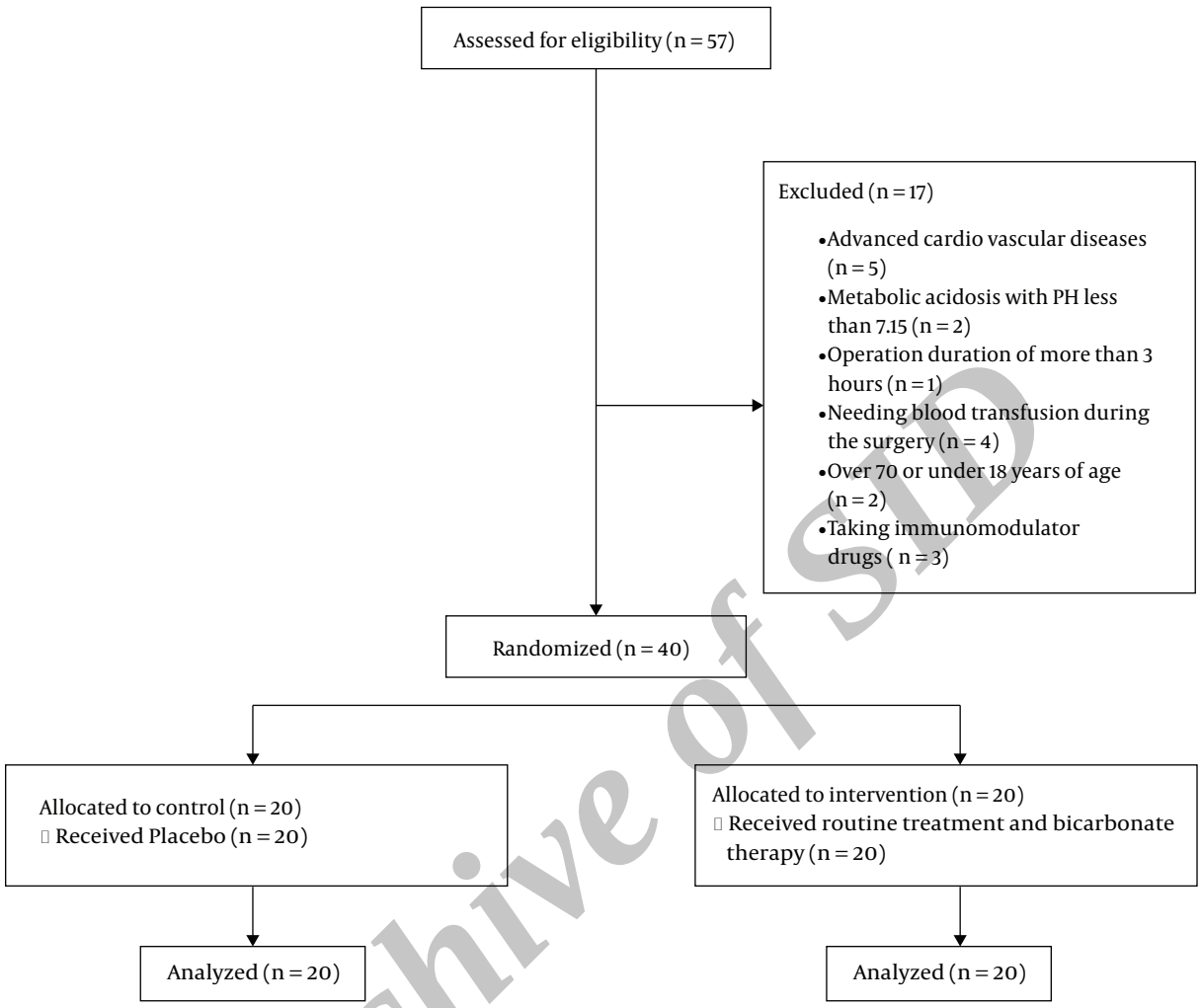

Figure 1. Flow chart of the study

saline fluid was used. The primary arterial blood sample and secondary arterial blood sample (during opening the clamp) were sent to a laboratory for the analysis of arterial pH, arterial bicarbonate (HCO_3), BE (Base Excess), and arterial carbon dioxide pressure ($PaCO_2$). During the first week after transplantation, BUN, Cr, and urine volume were measured for every 24-hour period. The studied cytokines (i.e., IL-2, IL-10, and IFN-γ) were measured at three-time points (i.e., before the intervention, after the surgery, and seven days after the surgery).

3.1. Statistical Analysis

Based on mean $\pm$ SD, at the stage of recovery, urine volume in the intervention group was 812 $\pm$ 492 and in the comparison group, was 377 $\pm$ 384 (12). The Type 1 error was 0.05 and the minimum power was 80%, and the sample size was calculated to be 17 individuals in each group.

Quantitative variables were expressed as mean $\pm$ SD and the categorical variables were presented with number and percent. To check the normality of the data, the Kolmogorov-Smirnov test was performed. In order to compare the control and intervention group in terms of acidosis biomarkers (PH, PCO_2, HCO_3, and BE) and cytokines (IL-2, IL-10, and IFN-γ), initially the amount of change of these biomarkers before and after the administration of the intervention (i.e., sodium bicarbonate or normal saline) was calculated and then the difference between the two groups was compared using the Mann-Whitney U test. The Wilcoxon test was used to evaluate the difference between the values before and after the acidosis biomarkers in each group. A General Linear Model (GLM)

and repeated measurement-Analysis of Variance (ANOVA) procedure was used to compare the changes occurring in BUN and Cr concentrations and 24-hour urine volume during the first seven days after the surgery between the two groups. The assumption of sphericity of this analysis was performed using Mauchly's Test of Sphericity. Since the assumption of sphericity had been violated for any of the above three variables, in this analysis, the comparisons were performed using the Greenhouse-Geisser test. The significance level in all tests was considered 0.05. Data analysis was performed using SPSS 18.

4. Results

A total of 40 patients who were ESRD candidates for renal transplant surgery and eligible for inclusion in the study participated in this study. There were 29 male participants (14 in the intervention group and 15 in the control group) and 11 female participants (six in the intervention group and five in the control group). The mean age and baseline values of the measured outcomes in the two groups are presented in Table 1. As it can be seen, in general, the two groups were similar in terms of the base values of the variables studied.

Based on the results of the Wilcoxon test, there was no significant difference between the baseline values of PH, HCO_3, BE, and PCO_2 and those measured after the surgery in the intervention group, however, in the control group, the postoperative values of PH, HCO_3, and BE were significantly lower than the baseline values (Table 2).

The comparison of changes in PH, HCO_3, BE, and PCO_2 values of the two groups before and after intervention was done using the Mann-Whitney U test. The results of these comparisons are presented in Table 2. In the intervention group, the observed changes in the PH, HCO_3, BE, and PCO_2 biomarkers were incremental, and in the control group, the changes occurred in PH, HCO_3, and BE biomarkers in contrast to the intervention group were decreasing, and the changes occurred in PCO_2 were incremental in both groups. However, there was a significant difference between the two groups in terms of the changes that occurred in pH, HCO_3, and BE values.

In Table 3, the changes in IL-2, IL-10, and IFN-γ biomarkers immediately after surgery and on the seventh day after surgery in the intervention and control groups are shown as compared to baseline values. As it can be observed, in the intervention group, IFN-γ, and IL-10 during recovery time, as compared to baseline values before intervention, increased and IFN-γ on the seventh day, IL-10 on the seventh day, and IL-2 during recovery time and on the seventh day, as compared to baseline values before intervention, reduced. In the control group, as opposed to the intervention group, the change in IFN-γ on the seventh day decreased and the change occurred for other biomarkers was similar to that of the intervention group. However, the Mann-Whitney U test showed no significant difference between the changes in the values of these biomarkers between the two groups.

The Greenhouse-Geisser test showed that the mean concentration of Cr and BUN, as well as the mean urine volume in both groups, were decreased with a significant statistical difference from the first day to the seventh day after the surgery (Table 4). The mean creatinine every seven days, mean BUN on days four to seven, and mean urine volume on days one to six in the control group were more than those of the intervention group. However, comparing these trends between the two groups, the Greenhouse-Geisser test revealed that the decreasing trend showed a significant difference between the two groups only in the case of BUN (Table 3 and Figure 2).

Table 1. Baseline Variables in Study Groups[a]

	Intervention Group	Control Group
Age, y	44.2 ± 12.4	40.0 ± 13.0
PH	7.30 ± 0.1	7.42 ± 0.1
HCO_3, mmol/L	16.46 ± 4.1	19.78 ± 2.5
BE, mmol/L	-10.62 ± 4.3	-4.74 ± 3.3
$PaCO_2$, mmHg	32.35 ± 7.3	30.15 ± 3.7
IFN-γ, pg/mL	9.67 ± 3.5	9.66 ± 1.8
IL-10, pg/mL	14.23 ± 18.7	12.11 ± 23.1
IL-2, pg/mL	7.58 ± 2.6	7.67 ± 3.2

Abbreviations: BE, base excess; HCO_3, bicarbonate; IFN-γ, Interferon gamma; IL-2, Interleukin 2; IL-10, Interleukin 10; $PaCO_2$, arterial pressure of CO_2 gas.
[a]Values are expressed as mean ± SD.

5. Discussion

In the present study, the effect of the prescription of sodium bicarbonate prior to renal transplant surgery on acidosis markers was investigated. While the levels of PH, HCO_3, and BE were increased in the group receiving sodium bicarbonate, in the comparison group receiving normal saline, there was a decrease in the amount of these markers, and the statistical test showed that the mean change occurred in these three markers revealed a significant difference between the two groups. In a randomized trial of 120 patients being candidates for renal transplant surgery, also in the intervention group who underwent tight acidosis control by the infusion of sodium bicarbonate, compared to the comparison group who underwent non-tight acidosis control, and among whom bicarbonate

Table 2. Within-Group Comparison of Before-After and Between-Group Comparison of the Changes in Acidosis Biomarkers[a]

Variable	Intervention Group			Control Group			Change		
	Before	After	P Value[b]	Before	After	P Value[b]	Intervention Group	Control Group	P Value[c]
PH	7.30 ± 0.1	7.31 ± 0.1	0.977	7.42 ± 0.1	7.35 ± 0.1	< 0.001	0.01 ± 0.1	-0.08 ± 0.1	< 0.001
HCO_3	16.46 ± 4.1	16.82 ± 3.9	0.779	19.78 ± 2.5	17.11 ± 1.9	< 0.001	0.36 ± 2.9	-2.67 ± 2.1	0.001
BE	-10.62 ± 4.3	-10.00 ± 3.2	0.904	-4.74 ± 3.3	-8.53 ± 3.2	< 0.001	0.61 ± 4.2	-3.8 ± 2.6	< 0.001
PCO_2	32.35 ± 7.3	33.15 ± 9.9	0.518	30.15 ± 3.7	31.55 ± 5.5	0.887	0.8 ± 5.4	1.4 ± 5.3	0.799

Abbreviations: BE, base excess; HCO_3, bicarbonate; $PaCO_2$, arterial pressure of CO_2 gas.
[a]Values are expressed as mean ± SD.
[b]Wilcoxon test.
[c]Mann-Whitney U test.

Table 3. Comparison of Inflammatory Biomarkers Between the Two Groups[a]

Variable	Intervention Group	Control Group	P Value[b]
Change in IFN-γ on 1st day versus baseline	0.35 ± 2.4	1.14 ± 3.2	0.778
Change in IFN-γ on 7th day versus baseline	-0.85 ± 2.5	0.27 ± 2.4	0.795
Change in IL-10 on 1st day versus baseline	15.54 ± 28.8	2.79 ± 31.6	0.367
Change in IL-10 on 7th day versus baseline	-11.44 ± 19.3	-9.22 ± 23.3	0.538
Change in IL-2 on 1st day versus baseline	-0.23 ± 0.7	-0.42 ± 2.6	0.641
Change in IL-2 on 7th day versus baseline	-0.58 ± 1.3	-0.22 ± 1.9	0.206

Abbreviations: IFN-γ, Interferon gamma; IL-10, Interleukin 10; IL-2, Interleukin 2.
[a]Values are expressed as mean ± SD.
[b]Mann-Whitney U test.

infusion was allowed only in case of severe metabolic acidosis, PH and BE increased and decreased respectively (17). In another clinical trial comparing the effects of normal saline and Plasmalyte on acid-base balance in patients undergoing renal transplant surgery, the values of PH, HCO_3, and BE in post-transplantation periods in the group receiving normal saline was lower than those of the Plasmalyte group (18). Moreover, in another clinical trial, the group receiving normal saline compared with those receiving Plasmalyte and Ringer's lactate had a higher reduction in PH and BE (19). Generally, renal damage makes the patient suffer from hyperchloremic metabolic acidosis, and the administration of normal saline as a hypertonic solution with high levels of chloride can exacerbate acidosis (19). Normal saline can produce acidosis through two mechanisms: (1) dilutional acidosis, which is produced by diluting extracellular bicarbonate with a large volume of bicarbonate fluid or diluting the concentration of Strong ions by changing the free water composition and (2) hyperchloremic acidosis resulting from hypercalcemia (18). Although in the present study serum bicarbonate concentration after transplantation in the normal saline group was lower than that of the bicarbonate group, due to the fact that these two mechanisms can be distinguished through measuring the concentration of BE_{Fw} (base excess caused by changes in free water) and BE_{cl} (base excess caused by changes in chloride) (20), the diagnosis of the type of the mechanism causing acidosis in this study was not possible. However, the overall result was that the incidence of acidosis in the group receiving normal saline was significantly higher, therefore, the administration of sodium bicarbonate increasing the levels of PH, HCO_3, and BE prior to renal transplantation could reduce the risk of acidosis.

There was no significant difference between the changes in the concentration of inflammatory biomarkers of IFN-γ, IL-10, and IL-2 in the two groups on day one and seven after transplantation. In an observational study, there was no significant difference in the inflammatory biomarkers including IL-6 and C-reactive protein among hemodialysis patients who were divided based on the concentrations of bicarbonate (mmol/L) and PH into three groups of A ($PHCO_3 \leq 21$, PH < 7.38), B ($PHCO_3$ between 21 - 26 and PH between 7.38 - 7.42), and C ($PHCO_3 > 26$, PH > 7.42) (21). However, other evidence suggests a relationship between inflammatory processes and metabolic acidosis. In a laboratory study, the production of tumor necrosis factor α (TNFα) was increased by peritoneal macrophages after their culture in an acidic cell culture medium (21). An interventional study performed on eight patients with continuous ambulatory peritoneal dialysis discov-

Table 4. Comparison of Renal Function Biomarkers Between the Two Groups[a]

Variable	Intervention Group	Control Group	P Value[a]
Cr, mg/dL			0.564
1st day	3.54 ± 1.5	3.95 ± 1.6	
2nd day	2.33 ± 0.9	2.34 ± 1	
3rd day	1.51 ± 0.4	1.55 ± 0.6	
4th day	1.22 ± 0.2	1.29 ± 0.4	
5th day	1.22 ± 0.3	1.33 ± 0.3	
6th day	1.15 ± 0.3	1.31 ± 0.4	
7th day	1.11 ± 0.2	1.32 ± 0.4	
P value	< 0.001	< 0.001	
BUN, mg/dL			0.018
1st day	85 ± 27.3	72.85 ± 24.4	
2nd day	65.4 ± 23	54.55 ± 20	
3rd day	55.35 ± 15.6	46.55 ± 16.2	
4th day	50.9 ± 13.3	51.3 ± 19	
5th day	48.9 ± 11.5	53.45 ± 17.4	
6th day	48.9 ± 12.3	52.3 ± 19.1	
7th day	47.5 ± 11.7	52.7 ± 21.4	
P value	< 0.001	< 0.001	
Ur. V, mL			0.243
1st day	16069.5 ± 6496.5	18545 ± 6375.7	
2nd day	7562.5 ± 3248.2	9975 ± 4030.3	
3rd day	5700.45 ± 2498.3	6567.5 ± 2025.1	
4th day	4705 ± 1929.6	5100 ± 1795.7	
5th day	4792.5 ± 1116.8	5095 ± 1498.2	
6th day	4390 ± 1074.8	5010 ± 2032.8	
7th day	5595 ± 5442.2	4797.5 ± 1735	
P value[a]	< 0.001	< 0.001	

Abbreviations: BUN, blood urea nitrogen; Cr, creatinine; Ur.V, urine volume.
[a]Values are expressed as mean ± SD.
[b]GLM repeated measurement analysis (Greenhouse-Geisser).

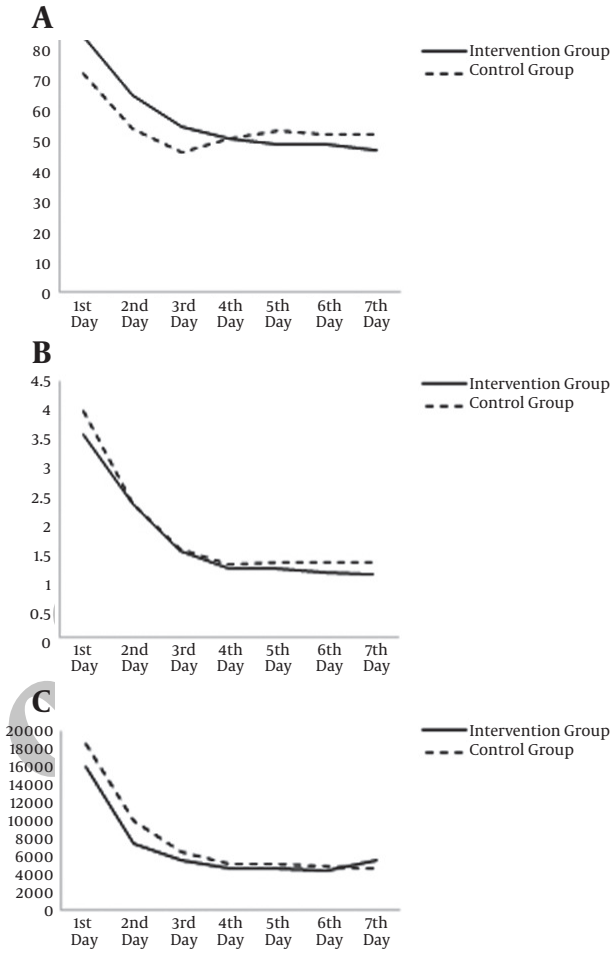

Figure 2. Changes in renal function biomarkers during first 7 days after surgery. A, blood urea nitrogen-BUN (mg/dL); B, creatinine (mg/dL) C) urine volume (mL).

ered that following increased serum bicarbonate levels resulting from the administration of sodium/calcium bicarbonate, the concentration of TNFα was significantly decreased (22). Although blood cytokine levels are high in patients with chronic renal failure, and laboratory studies suggest an increase in protein catabolism following TNFα injection in rats, the available data was inadequate to show a causal relationship between metabolic acidosis and inflammatory cytokines (23). On the other hand, due to the fact that high levels of IFN-γ are associated with an increase in creatinine concentrations in the first 5 years after kidney transplantation and high blood levels of IFN-γ and IL-10 with acute rejection, it is of prime importance to focus on the concentration of inflammatory cytokines and maintain them at the optimal level in patients undergoing kidney transplantation (24).

A pilot clinical trial on 100 patients revealed that the administration of sodium bicarbonate effectively improved renal function in patients undergoing cardiac surgeries and exposed to postoperative acute renal dysfunction (25). To evaluate renal function in the two groups, the mean concentrations of Cr and BUN, as well as the mean urine volume were measured in the first seven days after transplantation. According to some studies, the cause of better renal function in the group receiving bicarbonate was acidosis control by sodium bicarbonate (26).

The mean urine volume in both groups showed a significant decrease from day one to day seven after transplantation. However, no significant difference was ob-

served between the two groups. In a study, the best cut point (with a sensitivity of 97% and a specificity of 40%) of 24-hour urine volume on the seventh day after transplantation to predict the poor function of the transplanted kidney was considered 1500 mL (27). Based on this cut point, none of the patients studied had a volume of urine less than 1500 mL from day one to seven. Therefore, it could be assured that the studied patients in both groups had a good urine volume. The mean concentration of Cr in both groups showed a significant decrease from day one to day seven after transplantation. In all the first to seventh measurements, the mean of this variable in the bicarbonate group was non-significantly lower than that of the normal saline group. Similarly, in the study by Etezadi et al. (17), creatinine concentration in both groups (i.e., the group infused by sodium bicarbonate and the one infused by sodium bicarbonate only in condition of severe acidosis) showed a decreasing trend from day one to day seven and in all measurements, the respective values were lower in the group treated with sodium bicarbonate than in the other group; thus, the result of the present study was in line with that of this study (17). In another randomized clinical trial, the mean creatinine concentration on day three, in week one, and in month six after kidney transplantation was higher in the normal saline group (n = 26) than the Ringer's lactate group (n = 24). In this study, sodium bicarbonate was prescribed for eight patients from the normal saline group undergoing metabolic acidosis during surgery (26). According to the improvement of the volume of urine and serum creatinine in this group of patients and patients in two other surgical studies (27, 28), the researchers suggested that the harmful effects of normal saline could be attributed to metabolic acidosis and acidemia (18). Consequently, considering that serum creatinine level is considered as the gold standard for measuring renal function and estimating the glomerular filtration rate (29), the evaluation of its amount and trend of changes in renal transplant patients should be specifically considered.

On the other hand, the trend of concentration changes of BUN on the first to third postoperative days was decreasing in both groups and in the normal saline group it was lower than the bicarbonate group, however, on the fourth day, the mean BUN concentration in the normal saline group was increasing and had higher values than the bicarbonate group. In the study conducted by Etezadi et al. BUN concentration in the group treated with sodium bicarbonate was decreasing from the first day to the third day after transplantation, while in the control group, this biomarker on the second day compared to the first day was decreased but it rose again on the third day (17). A probable reason for such an increase in BUN in the normal saline group was the incidence of significant acidosis (i.e., a significant decrease in PH, BE, and HCO_3) in this group due to the fact that BUN, as one of the main indicators of renal function evaluation (30), could be increased under the influence of acidosis, and a significant decrease in BUN could be observed after the correction of acidosis (31).

The present study was affected by several limitations. Low sample size led to the violation of the assumption of normality for many of the variables under study and therefore, the impossibility of using parametric tests. No significant differences between the two groups regarding many of the investigated markers could be due to the lower power of the nonparametric tests applied. On the other hand, the present study was a single center study. Given that the duration of surgery and many other factors can vary among different institutions, these factors can affect the outcomes. However, the main results of the study did not significantly differ from those of the existing studies. All in all, it is recommended to investigate the effect of sodium bicarbonate on the prevention of the incidence of acidosis after transplantation in future studies by using multi-centered studies and higher sample sizes.

5.1. Conclusion

The current study presented that the patients who received sodium bicarbonate had a better status than normal saline recipients in terms of maintaining acid-base balance, inflammatory indexes, and renal function. Therefore, it can be concluded that the administration of sodium bicarbonate prior to renal transplantation helps the patient prevent metabolic acidosis and improves renal function by significantly decreasing creatinine and BUN concentrations.

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