Original Article

Efficacy of stepwise sodium profile versus individualized dialysate sodium in blood pressure control among hemodialysis patients

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Abstract

Background: Hypertension is very common in patients with end-stage renal disease and accelerates cardiovascular morbidity and mortality. The most important factor in achieving normal blood pressure in these patients is reaching dry weight. Sodium and extracellular fluid balance play a vital role in this regard. Considering the lack of consensus about the efficacy of stepwise sodium profile and individualized dialysate sodium, this study aimed to determine the superior method for blood pressure control in hemodialysis patients.

Materials and Methods: In a quasi-experimental study, patients satisfying the inclusion criteria were enrolled through convenience sampling. The patients were randomly assigned to two groups of stepwise sodium profile and individualized dialysate sodium. Information record form was used for data collection. Data were analyzed with paired and independent *t*-test and descriptive statistics using SPSS for Windows 20.0.

Results: Patients in the two groups were similar in qualitative and quantitative background variables. While systolic blood pressure significantly decreased following hemodialysis with individualized dialysate sodium ($P < 0.001$), there was no significant difference between pre- and post-dialysis systolic blood pressure values using stepwise sodium profile ($P = 0.060$). Individualized dialysate sodium caused greater change in the mean systolic blood pressure than stepwise sodium profile did ($P = 0.040$). Pre- and post-dialysis diastolic blood pressure values showed significant differences in both groups ($P < 0.001$ using individualized dialysate sodium and $P = 0.009$ using stepwise sodium profile). However, the mean changes in diastolic blood pressure of the two groups were not significantly different ($P = 0.295$).

Conclusions: We found no significant difference in interdialytic weight gain and blood pressure control by the two methods. The change in systolic blood pressure was lower in the stepwise profile method than in the individualized dialysate sodium method, and this method did not cause interdialytic hypertension. So, by adjusting the dialysis solution with regard to plasma sodium levels, lead to more blood pressure control. Meanwhile, the two groups were not significantly different in the mean changes of diastolic blood pressure.

Key words: Dialysate, hemodialysis, hypertension, interdialytic weight gain

Introduction

Hypertension, a major cause of end-stage renal failure, remains persistent in a significant proportion of patients undergoing hemodialysis. The condition is seen in 90% of hemodialysis patients,[1] and its under-treatment may lead to a variety of cardiovascular diseases, e.g. left ventricular hypertrophy, cardiac chamber dilatation, inappropriate distribution of coronary blood flow, myocardial ischemia, myocardial fibrosis, heart failure, and arrhythmias, which are considered as the most common cause of death among the mentioned population.[2] Meanwhile, reaching dry weight is considered as the first and most important factor in achieving normal blood pressure levels in these patients. Sodium and extracellular fluid balance plays a major role in blood pressure and interdialytic weight gain control and, thus, helps maintain dry weight.[3] Sodium concentration of the dialysate is critical in providing such balance. Shorter duration of dialysis and increased ultrafiltration rate following technological advancements in the field of hemodialysis have brought about hypotension, disequilibrium syndrome, and muscle cramps, the reduced

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Submitted: 20-Apr-13; Accepted: 11-Nov-13

incidence of which requires increased sodium concentration of the dialysate. Hypernatremic dialysates or sodium profiling has been used to control such effects.[4]

In sodium profiling, hyprenatremic dialysates are used at the beginning of the dialysis process. Sodium content of the dialysate is then gradually reduced to allow excess sodium to be removed from the blood. High sodium concentration in this method facilitates the movement of water from the interstitial space into the intravascular space and results in better maintenance of intravascular volume and fewer adverse effects during dialysis. However, some believe that high concentrations of sodium in sodium profiles will lead to not only increased thirst and interdialytic weight gain (which means the need for removing greater volumes of fluids to reach dry weight and higher frequency of hypotension) but also hypertension. Hence, sodium content of the dialysate has to be regulated according to each patient's plasma sodium level before dialysis.[2]

In contrast, other researchers suggest that sodium profiles reduce dialysis complications and provide patient comfort without affecting interdialytic weight gain. They thus believe that such procedures are beneficial to patients facing difficulty in reaching dry weight due to the adverse effects of dialysis.[5,6] There have also been studies indicating reduced sodium concentration of the dialysate to be associated with lower interdialytic weight gain, fewer complications during hemodialysis, and more favorable blood pressure.[7,8]

Considering the lack of consensus on the use of sodium profiles and isonatric dialysate (solutions in which the sodium content is adjusted based on the patient's plasma osmolarity), we aimed to study the effects of these two methods on hypertension among hemodialysis patients.

Materials and Methods

Ethical considerations

Ethical approval was obtained from the local research ethics committee of Isfahan University of Medical Sciences. The study's purpose and process were explained to subjects in full prior to participation. The participants autonomously decided whether to participate and signed the "informed consent" based on their decisions.

This quasi-experimental study was conducted in Noor and Amin Hospitals, Isfahan, Iran in 2012. A total of 40 non-diabetic, hypertensive patients on three times per week hemodialysis were recruited using convenience sampling. Dialysis was performed using sodium bicarbonate solutions and low-flux membranes, and had an adequacy of $Kt/V \geq 1.2$ (where K, t, and V were dialyzer clearance of urea, dialysis time, and volume of distribution of urea, approximately equal to patient's total body water, respectively).

The participants signed informed consent forms and had the right to withdraw from the study at any stage. The adequacy of hemodialysis (Kt/V) among the eligible subjects was measured in the beginning of the study. In order to calculate Kt/V, blood samples were obtained before and after hemodialysis, urea tests were performed, and the ratios were calculated using the dialysis adequacy calculation software available online (http://www.merah.ir/home/index.php?option=com_wrapperandview=wrapperandItemid=15). The software uses urea levels before and after dialysis, ultrafiltration rate, and patient's weight after hemodialysis to calculate dialysis adequacy.

Afterward, the eligible patients were included and allocated to two groups using a table of random numbers. The two groups received nine sessions of hemodialysis through either stepwise sodium profile or individualized dialysate sodium.[8] Since we intended to adjust dialysate sodium levels according to each patient's mean plasma sodium concentration, all eligible patients first underwent five sessions of hemodialysis with dialysates containing standard sodium levels (138 mEq/l). Before each dialysis session, the patients' plasma sodium concentrations were measured by an EasyLyte electrolyte analyzer (made in USA) using current ion-selective electrode technology (which measures sodium ion activity instead of its concentration). This method prevents false reports of hyponatremia due to changes in protein levels or blood lipids. After five sessions, the mean plasma sodium concentration of each patient was calculated and recorded. During the next nine sessions of hemodialysis, the dialysate sodium level was adjusted based on the obtained value for each individual. During individualized adjustments, the dialysate sodium level was set at 135 me/lit for patients with mean serum sodium levels of less than 137 and 137 for others. Unvarying dialysate sodium level was maintained throughout the process of dialysis (Sayarlioglu *et al*. 2007). In the stepwise sodium profile group, the upper limit was considered as 146 and the lower limit was defined according to the above-mentioned method.

Blood pressure measurements were performed before the dialysis, at the first, second, and third hours of the process, and at the end of it using a single standard mercury sphygmomanometer (ALPK-2 made in Japan) and based on Korotkoff sounds. The participants' regular blood pressure medication regimen remained unchanged. As the subjects were randomly assigned to the study groups, it was impossible to match the two groups in terms of blood pressure before hemodialysis. Hence, in inter-group comparisons of blood pressure after dialysis, the effects of blood pressure before dialysis were kept constant and covariance analysis was applied. Considering that the researcher and co-researcher measured the participants' blood pressure in the course of the study, inter-rater reliability of the measurements was first tested on a sample of 10 subjects and a correlation coefficient of 95% was obtained.

None of the subjects were excluded from the study since fixed antihypertensive treatment regimen, membrane type, and frequency of hemodialysis were used and no patient had episodes of hypotension (reduction of 40 and 20 mmHg in systolic and diastolic blood pressure, respectively).[15] A Fresenius 4008 dialysis machine (made in Germany) at 36°C was used for all patients. Blood and dialysate flow rates were set at 300-350 and 500 ml/min, respectively. Hemodialysis sessions lasted for 4 h.

All statistical analyses were performed in SPSS for Windows 20.0 (SPSS Inc., Chicago, IL, USA). *P* values less than 0.05 were considered as statistically significant.

Results

The two groups were not significantly different regarding quantitative variables (age, duration of hemodialysis, and hemodialysis adequacy level) or qualitative variables (gender, type of vascular access, the use of erythropoietin, and antihypertensive drugs) [Table 1].

According to independent *t*-test, the mean systolic blood pressure of the two groups was not significantly different either before or after hemodialysis ($P = 0.437$ and 0.620, respectively). However, analysis of covariance showed that if the mean systolic blood pressure of the two groups were exactly similar before the intervention, there would have been a significant difference between the values after the intervention ($P = 0.04$). While the mean systolic blood pressure significantly decreased after hemodialysis using individualized dialysate sodium ($P < 0.001$), no such difference was detected between the values before and after hemodialysis using stepwise sodium profile ($P = 0.06$) [Table 2]. The mean changes in systolic blood pressure were thus significantly higher using the individualized dialysate sodium than with the stepwise sodium profile ($P = 0.040$).

Independent *t*-test indicated that the two groups were not significantly different in terms of mean diastolic blood pressure before hemodialysis ($P = 0.206$). Analysis of covariance also suggested that if the mean diastolic blood pressure values before the intervention were exactly the same in both methods, no significant difference

Table 1: Baseline characteristics of the patients presented as mean (standard deviation) or number (%)

	Individualized dialysate sodium	Stepwise sodium profile	*P* value
Age (years)	53.7 (15.62)	56 (19.5)	0.677
Sex (male)	14 (70%)	12 (60%)	0.507
Duration of hemodialysis (years)	3.76 (2.94)	3.70 (3.46)	0.957
K*T/V*	1.4 (0.2)	1.3 (0.1)	0.166
Vascular access			
Arteriovenous fistula	11 (55%)	14 (70%)	0.362
Arteriovenous graft	1 (5%)	0	
Venovenous	8 (40%)	6 (30%)	
Use of erythropoietin (yes)	16 (80%)	17 (85%)	0.500
Antihypertensive drugs			
Alpha-blockers	1 (5%)	1 (5%)	0.159
Calcium channel blockers	10 (50%)	8 (40%)	
Beta-blockers	8 (40%)	12 (60%)	
Angiotensin-converting enzyme inhibitors	9 (45%)	8 (40%)	

Table 2: Mean pre- and post-dialysis systolic blood pressure in individualized dialysate sodium and stepwise sodium profile groups

	Pre-dialysis systolic blood pressure		Post-dialysis systolic blood pressure		Paired *t*-test	
	Mean	SD	Mean	SD	*t*	*P*
Individualized dialysate sodium	136.11	13.10	124.85	12.22	5.75	<0.001
Stepwise sodium profile	132.66	14.63	127.25	17.83	19.99	0.060
Independent *t*-test						
t	0.78		0.49		-	
P	0.437		0.620		-	

SD: Standard deviation

Table 3: Mean pre- and post-dialysis diastolic blood pressure in individualized dialysate sodium and stepwise sodium profile groups

	Pre-dialysis diastolic blood pressure		Post-dialysis diastolic blood pressure		Paired *t*-test	
	Mean	SD	Mean	SD	*t*	*P*
Individualized dialysate sodium	79.55	6.21	74.05	6.01	5.65	<0.001
Stepwise sodium profile	77.25	5.05	73.80	6.44	2.91	0.009
Independent *t*-test						
t	1.29		0.24		-	
P	0.206		0.808		-	

SD: Standard deviation

Table 4: Interdialytic weight gain in individualized sodium adjustment and stepwise sodium profile groups

	Individualized dialysate sodium		Stepwise sodium profile		Independent *t*-test	
	Mean	SD	Mean	SD	*t*	*P*
Interdialytic weight gain	2.48	1.06	2.88	0.82	1.31	0.372

SD: Standard deviation

would have been observed in the values after the intervention ($P = 0.182$). Both methods significantly reduced the mean diastolic blood pressure ($P < 0.001$ and $P = 0.009$ using individualized dialysate sodium and stepwise sodium profile, respectively) [Table 3]. Changes in the mean diastolic pressure were not significantly different between the two methods ($P = 0.259$). The two groups did not have a significant difference in the mean interdialytic weight gain ($P = 0.372$) [Table 4].

Discussion

Studies have found that 80-90% of patients with hypertension have chronic increase in blood volume, and thus, hypertension is often controlled by removal of fluids. Salt and water retention play a vital role in the pathogenesis of hypertension during hemodialysis. In patients with hypertension, sodium and potassium balance is crucial to endothelium-dependent vasodilation. Research has indicated that sodium retention decreases nitric oxide (a vasodilator produced by vascular endothelium) synthesis and increases asymmetric dimethylarginine levels. Asymmetric dimethylarginine, which inhibits nitric oxide production, accumulates in the body of patients with chronic renal failure and is only reduced by 65% through hemodialysis.[9]

The present study also revealed that individualized dialysate sodium levels reduce sodium accumulation and lead to better control of hypertension in patients. Similarly, the findings of Farmer *et al*., Ferraboli *et al*., Lambie *et al*., Ozturk *et al*., Davenport *et al*., Manlucu *et al*., and Mendoza *et al*. Showed that random dialysate sodium reduction leads to lower systolic blood pressure after hemodialysis.[7,10-15] However, Selby *et al*. found that lowered dialysate sodium levels did not affect the patients' blood pressure. They concluded that reduced dialysate sodium without restricted sodium diet (2000 mg daily) cannot effectively control blood pressure in hypertensive patients.[16] It is noteworthy that Selby *et al*. used a biofeedback system to control dialysate sodium levels[16] while we adjusted sodium levels based on the patients' plasma sodium concentration.

de Paula *et al*. showed that isonatric dialysates did not significantly change blood pressure. Nevertheless, isonatric dialysates led to better blood pressure control in patients with uncontrolled hypertension. The researchers thus argued that individualized dialysate sodium increases sodium balance which, in turn, decreases vascular resistance and improves blood pressure control. They also reported a direct relationship between the concentration gradient of sodium and patients' blood pressure. Hence, it seems that patients with uncontrolled hypertension had lower plasma sodium levels compared to other patients (controlled hypertension) and that individualized dialysate sodium with lower concentration gradient of sodium and decreased sodium accumulation could control hypertension better in these patients.[8]

In the present study, there was no statistically significant difference in the mean systolic blood pressure before and after hemodialysis using stepwise sodium profile. Apparently, stepwise adjustment of sodium profile based on the patient's blood osmolarity does not increase systolic blood pressure before hemodialysis or interdialytic hypertension. The initial and final concentrations of dialysate sodium in the current study were selected based on blood osmolarity and fell in the normal range for human body. Since these values led to better results compared to studies where sodium levels were out of the normal range, there is no need for excessive increase of sodium when using sodium profiles.

Song *et al*.'s study showed that mean systolic pressure before hemodialysis in patients of group 3 sodium profiles and ultrafiltration profile 3 did not show a significant difference compared to the control group, which is similar to the findings of the present study.[6]

Contrary to our findings, Meira *et al*. Reported stepwise sodium profile to increase systolic blood pressure before hemodialysis compared to the control group. They set the initial and final concentrations of sodium at 147 and 139 mEq/l. [5] We selected 146 as the initial sodium concentration and adjusted the final value based on the patient's mean plasma sodium concentration. Hence, the neutral sodium balance prevented increments in systolic blood pressure before hemodialysis.

Although the mean diastolic blood pressure significantly decreased in both groups in the present study, the mean diastolic blood pressure either before or after hemodialysis was not significantly different in the two groups. Similar to our findings, Manlucu *et al*. showed that gradual reduction of dialysate sodium through biofeedback systems decreases diastolic blood pressure. They indicated that lowering dialysate sodium level from 140 to 135 mEq/l decreased plasma sodium concentration from 137.8 to 135.6 mmol/l. Such a change improved interdialytic weight gain and blood pressure control through reducing sodium retention and stimulating thirst.[14]

Thein *et al*. suggested that gradual reduction of dialysate sodium is a safe method of decreasing diastolic blood pressure before and after hemodialysis without affecting the number of side effects during the procedure.[17] In a study by Mendoza *et al*., reducing dialysate sodium concentration from 140 to 134-136 mEq/l decreased diastolic blood pressure before hemodialysis, but did not cause a significant difference.[15]

Overall, data analysis revealed that compared to stepwise sodium profile, individualized dialysate sodium concentration could control systolic blood pressure after hemodialysis better.

Limitations

Examining the patients' sodium intake is recommended for further studies. Studies with larger sample size and longer duration are also warranted. Clinical Research Development Center. This article was derived from a master thesis of critical care with project number 391318, Isfahan University of Medical Sciences, Isfahan, Iran.

References

1. Chang TI. Systolic blood pressure and mortality in patients on hemodialysis. Curr Hypertens Rep 2011;13:362-9.
2. Brenner BM, Maarten W, Taal GMC, Philip A. Marsden Karl Skorecki, Alan SL YU. 2012. The Kidney. Lippincott, Williams and Wilkins: Elsevier; p. 2294, 2296,2322,2324,2331.
3. Frankliu, Jon, H.Laragh Charra B. Core Curriculum Fluid Balance, dry weight, and blood pressure in dialysis. Hemodial Int 2007;11:21-31.
4. Flanigan M. Hypertension in hemodialysis Patients: Dialysate composition and hemodialysis hypertension. Semin Dial 2004;17:279-83.
5. Meira FS, Poli DE, Figueiredo CE, Figueiredo AE. Influence of sodium profile in preventing complications during hemodialysis. Hemodial Int 2007;11:S29-32.
6. Song JH, Park GH, Lee SY, Lee SW, Lee SW, Kim MJ. Effect of sodium balance and the combination of ultrafiltration profile during sodium profiling hemodialysis on the maintenance of the quality of dialysis and sodium and fluid balances. J Am Soc Nephrol 2005;16:237-46.
7. Davenport A, Cox C, Thuraisingham R; Pan Thames Renal Audit Group. The importance of dialysate sodium concentration in determining interdialytic weight gains in chronic hemodialysis patients: The Pan Thames Renal Audit. Int J Artif Organs 2008;31:411-7.
8. de Paula FM, Peixoto AJ, Pinto LV, Dorigo D, Patricio PJ, Santos SF. Clinical consequences of an individualized dialysate sodium prescription in hemodialysis patients. Kidney Int 2004;66:1232-8.
9. Büssemaker E, Hillebrand U, Hausberg M, Pavenstädt H, Oberleithner H. Pathogenesis of hypertension: Interactions among sodium, potassium, and aldosterone. Am J Kidney Dis 2010;55:1111-20.
10. Farmer C, Donohoe P, Dallyn P, Cox J, Kingswood J, Goldsmith D. Low-sodium haemodialysis without fluid removal improves blood pressure control in chronic haemodialysis patients. Nephrology 2000;5:237-41.
11. Ferraboli R, Manuel C, Abensur H, Elias R, Luders C. Reduction of sodium dialysate for hypertensive HD patients: Analysis of beneficial and adverse effects. J Am Soc Nephrol 2002;13:211.
12. Lambie SH, Taal MW, Fluck RJ, McIntyre CW. Online conductivity monitoring: Validation and usefulness in a clinical trial of reduced dialysate conductivity. ASAIO J 2005;51:70-6.
13. Ozturk S, Taymez DG, Bahat G, Demirel R, Aysuna N, Sakar S, *et al*. The influence of low dialysate sodium and glucose concentration on volume distributions in body compartments after haemodialysis: A bioimpedance analysis study. Nephrol Dial Transplant 2008;23:3629-34.
14. Manlucu J, Gallo K, Heidenheim PA, Lindsay RM. Lowering postdialysis plasma sodium (conductivity) to increase sodium removal in volume-expanded hemodialysis patients: A pilot study using a biofeedback software system. Am J Kidney Dis 2010;56:69-76.
15. Mendoza JM, Sun S, Chertow GM, Moran J, Doss S, Schiller B. Dialysate sodium and sodium gradient in maintenance hemodialysis: A neglected sodium restriction approach? Nephrol Dial Transplant 2011; 26:1281-7.
16. Selby NM, Taal MW, McIntyre CW. Comparison of progressive conductivity reduction with diacontrol and standard dialysis. ASAIO J 2007;53:194-200.
17. Thein H, Haloob I, Marshall MR. Associations of a facility level decrease in dialysate sodium concentration with blood pressure and interdialytic weight gain. Nephrol Dial Transplant 2007; 22:2630-9.

How to site: Shahgholian N, Hashemi MS, Shahidi S. Efficacy of stepwise sodium profile versus individualized dialysate sodium in blood pressure control among hemodialysis patients. Iranian Journal of Nursing and Midwifery Research 2015;20:12-6.

Source of Support: Isfahan University of Medical Sciences, **Conflict of Interest:** None declared.