Effect of Dialysate Sodium Concentration on Interdialytic Increase of Potassium

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Abstract. To evaluate the role of plasma tonicity in the postdialysis increment of plasma potassium ([K+]p), the outcome of two hemodiafiltration treatments that differed only in the Na+ level in dialysate (NaD)—143 mmol/L (high dialysate sodium concentration [H-NaD]) and 138 mmol/L (low dialysate sodium concentration [L-NaD])—were compared in the same group of uremic patients from the end of treatment (T0) to the subsequent 30 to 120 min and up to 68 h. Kt/V and intradialytic K+ removal were comparable. At T0, plasma [Na+] was 145 ± 1 and 137 ± 1 mmol/L after H-NaD and L-NaD, respectively (P < 0.001). The difference in plasma tonicity persisted from T0 to T68 h. At T120, [K+] was increased from the T0 value of 3.7 ± 0.2 to 4.7 ± 0.2 mmol/L (P < 0.05) after H-NaD, whereas it was unchanged after L-NaD. The change of [K+] was still different after 68 h (+76 ± 10% and +50 ± 7% in H-NaD and L-NaD, respectively; P < 0.05). Of note, in the first 2 h after the end of treatment, bioimpedance analysis revealed only in H-NaD a significant 11 ± 3% decrement of phase angle that is compatible with a decrease of intracellular fluid volume at the expense of the extracellular volume. Similarly, within the same time frame, in H-NaD, a significant reduction of mean corpuscular volume of red cells, associated with a 2 ± 1% decrease of the intracellular [K+], was observed. In contrast, mean corpuscular volume of red cells did not change and erythrocyte [K+] increased by 6 ± 1% after L-NaD (P < 0.005 versus H-NaD). Thus, hypertonicity significantly contributes to the increase of [K+] throughout the whole interdialytic period by determining intracellular fluid volume/extracellular volume redistribution of water and K+.

Hyperkalemia is a common and dangerous event in patients who are on maintenance hemodialysis (HD). The most prominent adverse effects are unpredictable and potentially lethal arrhythmias, respiratory depression, and enhanced weakness and fatigue (1). In these patients, HD is the primary method of potassium (K+) removal (2,3). However, the reduction of plasma K+ levels (p[K+]) by HD is often significantly impained by the postdialysis rebound of K+, i.e., the increment of p[K+] detectable within the initial few hours after treatment (4). The magnitude of K+ rebound varies, depending on the pre-HD values of p[K+], from approximately 1 mmol/L in the absence of marked pre-HD hyperkalemia (5,6) up to levels sufficiently high to cause fatalities, as described in hyperkalemic patients with tumor lysis syndrome (7). These studies emphasize the importance of a periodic control of p[K+] during the interdialytic period in hyperkalemic patients even in the presence of normal levels at the end of the treatment.

Despite the clinical relevance of K+ rebound, no study has focused on the prevention of this potentially lethal complication. Indeed, the information on the underlying pathophysiologic mechanism is scarce and is limited to the observation that this phenomenon is not related to the intradialytic K+ removal (6). We have demonstrated previously that in patients with moderate renal failure, the infusion of 5% hypertonic NaCl solution is associated with an increment of p[K+] of approximately 0.6 mmol/L despite enhanced renal excretion of K+ and independently from acid-base or hormonal mechanisms (8). We concluded that plasma hypertonicity was the main determinant of hyperkalemia by inducing intra-/extracellular redistribution of K+ as a result of solvent drag. A similar phenomenon also has been reported in individuals with normal renal function (1).

Because p[K+] correlates with plasma tonicity, it is reasonable to hypothesize that a reduction of extracellular sodium concentration may prevent K+ rebound in HD patients. The present study verifies this hypothesis by evaluating the influence of sodium dialysate concentration on the postdialysis p[K+] levels and the concurrent transcellular shift of water and K+. To exclude any disturbing factor in this analysis, we performed the study with patients who had no additional risk of hyperkalemia. Patients were treated with soft hemodiafiltration; such a dialysis technique, characterized by combined diffusive and convective fluxes, reinfusion in postdilution of bicarbonate solution, and an ultrafiltration rate of 25 to 50 ml/min, allows an optimal control of p[K+] by ensuring more...
adequate acid-base balance and stability of systemic hemodynamics (9). We compared the effects of two different sodium dialysate concentrations, 138 and 143 mmol/L, that fall within the isotonic range commonly used in clinical practice to avoid drawbacks secondary to major changes of plasma osmolality and volume status (10,11).

Materials and Methods

Patients
To select patients with stable clinical conditions and with no major alterations of acid-base balance and K⁺ metabolism, we applied the following inclusion criteria: adult anuric uremic patients treated from at least 6 mo with soft hemodiafiltration and with sodium level in dialysate at approximately 140 mmol/L; absence of any acute illness in the last 3 mo; constancy of the main clinical features during the last 3 mo (dialysis modalities, diet and nutritional status, dry weight, arterial BP, medications, and routine laboratory measurements); p[K⁺] < 7.0 mmol/L and plasma bicarbonate > 18 mmol/L after the long interdialytic interval in the last 3 mo; absence of diabetes mellitus, heart failure (NYHA classes III to IV), or advanced liver disease and peripheral or pulmonary edema.

We studied, after obtaining informed consent, 12 patients (8 men, 4 women) with a mean age of 54 ± 4 yr (range, 31 to 70 yr). The underlying renal disease was primary glomerulonephritis in seven patients, nephroangiosclerosis in three patients, and polycystic disease in two patients. Before the study, the patients had been dialyzed from an average of 76 ± 10 mo (range, 12 to 120 mo). They had been treated regularly for 4 h, three times a week, with a delivered Kt/V dose, calculated according to the method of Davídidas (12), of at least 1.20 in the last 3 mo. All of them were prescribed a diet that contained approximately 1.0 g/kg body wt of protein and 30 to 35 kcal/kg body wt. In the last 3 mo, the protein catabolic rate (PCR), calculated with standard formula (13), averaged 1.24 ± 0.23 g/kg body wt with changes not exceeding 10%. During the study, they received only the following medications: calcium carbonate (4 patients), magnesium hydroxide plus aluminum hydroxide (8 patients), antihypertensive drugs (3 patients were taking calcium antagonists and 3 were treated with clonidine), epoetin (11 patients with a mean weekly dose of 6000 U), vitamin D₃ (2 patients), and H₂ antagonists (7 patients). The dose of medications did not vary in the two experimental steps.

Study Design
The study was a randomized, single-blind, crossover trial in the same group of 12 patients of two identical treatments of soft hemodiafiltration differing only in the sodium level in the dialysate, which was kept constant during the entire dialysis treatment:

- High dialysate sodium concentration: 143 mmol/L (H-Na⁺)
- Low dialysate sodium concentration: 138 mmol/L (L-Na⁺)

The treatment was delivered in each patient, at both experimental steps, with the same artificial system equipped with automatic device planning the ultrafiltration rate (Integra, Hospal, Bologna, Italy, or PMMA 2.0 m²; Filtryze B3-2, Toray-Hoechst, Milan, Italy), blood flow rate (25 to 35 ml/min), dialysate flow rate (500 ml/min), and ultrafiltration rate (25 to 35 ml/min). Also, the dialysate composition did not differ: bicarbonate, 39 mmol/L; acetate, 4.0 mmol/L; calcium, 1.5 mmol/L; magnesium, 0.5 mmol/L; and glucose, 1.0 g/L; the potassium level was 2.0 and 3.0 mmol/L in five and seven patients, respectively, and was kept constant in the two treatments. The composition of replacement fluid was identical (145 mmol/L Na⁺, 100 mmol/L Cl⁻, 45 mmol/L HCO₃⁻). Dialysate temperature was constantly kept at 36.5°C.

Patients randomly received the two different treatments on the last session before the long interdialytic interval. The second experimental session was performed 2 wk after the first treatment. During this period, patients were treated with soft hemodiafiltration with Na₀ of 140 mmol/L.

Blood samples were obtained before the treatment; at the end of treatment (T₀); and after 30, 60, 90, and 120 min through the dialysis needles left in place and in the following 24, 48, and 68 h by venipuncture. During the entire dialysis session and in the subsequent 2 h, all of the patients remained in bed and did not receive any food or beverage. Body weight, BP, and pulse rate were recorded hourly during the treatment and at each experimental time.

At each experimental time, we measured hematocrit and the plasma levels of K⁺, sodium, total protein, blood urea nitrogen (BUN), glucose, phosphate, osmolality, bicarbonate and pH, insulin, and aldosterone. We also assessed the PCR value, normalized for dry body weight (nPCR), from the BUN appearance during the interdialytic interval from T₀ to T68 (13). The predialysis sample was obtained before the infusion of saline or heparin and before starting the blood pump, whereas the postdialysis sample (T₀) was drawn after maintaining for 2 min a low blood flow rate (50 ml/min), in the absence of dialysate flow to minimize cardiopulmonary blood recirculation.

Erythrocyte Potassium
To determine whether changes of Na₀ cause transcellular shift of K⁺, we examined the intracellular K levels in erythrocytes (e[K⁺]). Non-hemolyzed blood samples were drawn before hemodiafiltration and after treatment, from T₀ to T120. Immediately after the blood sample was obtained, erythrocytes were separated from anticoagulated blood by centrifugation and processed within 1 h as described previously (14). Briefly, 1 ml of erythrocytes was washed with 1 ml of isoosmotic Tris 10 mM and choline chloride 140 mM solution to remove residual plasma cations. Thereafter, 1 ml of the washed cell suspension was added to 1 ml of hypotonic Tris 5 mM and ethylene-diaminetetraacetic acid 1 mM solution and stored for 24 h at 4°C to obtain the complete cell lysis. Then, samples were centrifugated at 3500 rpm for 5 min to remove cell membranes. Potassium concentration is expressed as millimoles per liter of erythrocytes. The mean corpuscular volume (MCV) of red cells was also assessed from the ratio between hematocrit (determined by ALC hematocrit centrifugette 4203, ALC Int., Milano, Italy) and the number of red cells (determined by H₂ System analyser, Technicon, Bayer, Germany).

Bioimpedance Analysis
Bioelectrical impedance analysis (BIA) is a technique used to evaluate indirectly body composition by injecting through the body a low-amplitude alternating electrical current (15). We used this technique to gain information on the transcellular shift of water under the two different experimental conditions. BIA analyzes the electrical characteristics of tissues; the two components that contribute to impedance are resistance (R), the pure opposition of the tissue to the flow of electrons, and reactance (Xc), reflecting the capacitance of cell membranes, tissue interfaces, and so forth (16). The BIA-derived phase angle (PhA) corresponds to the angular transformation of the ratio Xc/R (15). BIA measurements (R, Xc, and PhA) were obtained before the dialysis session and at each time of the postdialysis period; the electrodes were placed on the side free from the vascular access and were kept in place throughout the study to avoid replacement errors. Single-frequency BIA was determined at 50 kHz, with an
imp’d (model BIA 101 RJL, Akern, Firenze, Italy) according to the standard tetrapolar technique (15,16).

Analytical Determinations

The levels of potassium and sodium in plasma and dialysate were assessed by flame photometer (Beckman Instruments, Inc., Fullerton, CA) in triplicate (the coefficient of variation was always <1%); BUN, phosphate, total protein, and glucose were measured using an autoanalyzer (Olympus AU 560, Olympus Italia, Segrè-Milano, Italy). Blood pH and bicarbonate levels were analyzed by an automatic hemogas analyzer (ABL 625, Radiometer Copenhagen, De Mori, Italy). Plasma osmolality was measured by osmometer (model 250 D, S Fiske Associates Inc., Uxbridge, MA). Aldosterone and insulin levels were assessed by standard RIA (Aldoctk 2 and Insik 5, respectively, Sorin, Vercelli, Italy).

The amount of potassium removed (Kd) by the treatment was also determined according to the following formula (6): Kd = (Vc/Kc) – (Vp/Kp); where Vc is the volume of collected dialysate measured by collecting the entire effluent dialysate into a high-capacity box placed on a plate balance, KC is the K+ concentration in collected dialysate, VC is the fresh dialysate volume, and KD is the K+ concentration in fresh dialysate verified at the prehemofilter level.

Statistical Analyses

All of the values are reported as mean ± SEM. Intergroup comparisons were made by two-tailed t test for unpaired data, whereas intragroup comparisons were made by ANOVA for repeated measures followed by the Newman-Keuls as post hoc test. Linear regression analysis was also used where indicated. P < 0.05 was considered statistically significant.

Results

The two dialysis sessions did not differ in treatment time (H-NaD, 235 ± 14 min; L-NaD, 230 ± 14 min). As reported in Table 1, the sessions led to similar weight loss (2.9 ± 0.3 kg and 2.9 ± 0.2 kg) and reduction of blood volume, as evidenced by the same increment of hematocrit (10.8 ± 6% and 10.7 ± 6%), and serum total protein (19.9 ± 3% and 18.1 ± 3%); also, the delivered dialysate dose and K+ removal were similar. Both treatments were characterized by the absence of hypotensive episode, defined as a decrease in systolic pressure of ≥30 mmHg or a value <90 mmHg.

The two levels of NaD led to a different plasma tonicity during and after the dialysis session up to T68 h, as depicted by the plasma sodium (p[Na+]) levels (Figure 1). At T0, plasma osmolality was 298 ± 2.8 and 284 ± 1.4 mOsm/kg H2O after H-NaD and L-NaD, respectively (P < 0.001).

The different tonicity resulted in a diverse profile of p[K+] (Figure 2). Despite a comparable intradialytic decrement of p[K+] (−36 ± 3% at H-NaD and −34 ± 2% at L-NaD, not significant), only the H-NaD treatment was associated with a significant increase of p[K+] within the initial 2 h postdialysis. As for p[Na+], the different pattern of p[K+] changes in the two dialysis sessions persisted up to the end of the observation period. Of note, the K+ level measured 2 h after the end of dialysis were predictive of the p[K+] values detected in the subsequent period of follow-up. In fact, significant correlations were found between the p[K+] value at T120 and the values measured at T24 h (r = 0.80), T48 h (r = 0.71), and T68 h (r = 0.66) after H-NaD; similar results were obtained with L-NaD (T24 h, r = 0.72; T48 h, r = 0.69; T68 h, r = 0.78; P < 0.05).

The interdialytic protein intake, evaluated by nPCR determinations in the T0 to T68 h interval, was comparable (1.21 ± 0.21 and 1.23 ± 0.25 g/kg body wt per in H-NaD and L-NaD, respectively). Plasma tonicity also influenced the postdialysis increment of phosphate (Figure 3A); in contrast, no effect was observed on the variation of BUN (Figure 3B).

Table 2 describes the postdialysis variation of the main factors involved in the control of p[K+]. During the dialysis treatment, blood pH and bicarbonate, which were comparable at baseline, similarly increased in H-NaD and L-NaD. In the postdialysis period, while the value of blood pH was similar for the two modalities, plasma bicarbonate was slightly but significantly higher at H-NaD with respect to L-NaD; such a difference persisted at T120 but, as opposed to the changes of plasma Na+ and K+, disappeared in the subsequent period from T24 to T68 h. Plasma glucose level (mg/dl), which was significantly higher at the end of dialysis as compared with the predialysis values in both modalities (it increased from 90 ± 21 to 111 ± 20 and from 90 ± 19 to 114 ± 21 in H-NaD and L-NaD, respectively), did not vary in postdialysis and remained similar in H-NaD and L-NaD (at T120, the values were 107 ± 17 and 110 ± 15, respectively). Similarly, the insulin levels were unaffected by the two dialysate Na+ concentrations (Ta-

### Table 1. Changes of the indexes of volume state and dialysis efficiency in soft hemodiafiltration at high (143 mmol/L, H-NaD) and low (138 mmol/L, L-NaD) sodium dialysate concentration

<table>
<thead>
<tr>
<th></th>
<th>Body Weight (kg)</th>
<th>Mean BP (mmHg)</th>
<th>Hematocrit (%)</th>
<th>Serum Total Protein (g/dL)</th>
<th>Kt/V</th>
<th>K+ removal (mmol)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>H-NaD</td>
<td>71.3</td>
<td>68.4a</td>
<td>103</td>
<td>100a</td>
<td>32.9</td>
<td>36.5a</td>
</tr>
<tr>
<td>(3.4)</td>
<td>(3.3)</td>
<td>(2.2)</td>
<td>(4.0)</td>
<td>(0.8)</td>
<td>(1.3)</td>
<td>(0.1)</td>
</tr>
<tr>
<td>L-NaD</td>
<td>71.4</td>
<td>68.5a</td>
<td>102</td>
<td>100a</td>
<td>34.4</td>
<td>38.0a</td>
</tr>
<tr>
<td>(3.5)</td>
<td>(3.4)</td>
<td>(3.1)</td>
<td>(2.5)</td>
<td>(1.0)</td>
<td>(1.0)</td>
<td>(0.2)</td>
</tr>
</tbody>
</table>

Values are mean ± SEM.

a P < 0.05 versus predialysis value.
A slight but significant decrease of aldosterone levels was noted 2 h after H-NaD (\(P < 0.05\) versus \(T_0\); Table 2); however, no significant intergroup difference was detected at \(T_{120}\).

BIA measures were comparable in the two treatments at baseline and significantly increased after both sessions; however, a diverse pattern of variation was detected in the postdialysis \(T_0\) to \(T_{120}\) period. In the presence of a stable value of \(R\), \(X_c\) diminished by a greater extent in H-NaD than in L-NaD (at \(T_{120}\), the decrement versus \(T_0\) was 8.6\% and 1.6\%, respectively; \(P < 0.01\)). The combination of these changes resulted in a significant difference of the postdialysis values of PhA, which did not vary after L-NaD but progressively decreased after H-NaD (Figure 4A).

The pattern of the postdialysis variation of the MCV was comparable to that of PhA (Figure 4B). MCV, which was similar in predialysis (89.4 ± 1.8 fl at H-NaD and 90.2 ± 1.9 fl at L-NaD), was significantly lower at the end of H-NaD versus L-NaD. Thereafter, MCV progressively decreased after H-NaD, whereas it was unmodified in L-NaD.

In predialysis, e[K\(^+\)] did not differ significantly in H-NaD and L-NaD, (92.2 ± 1.8 and 95.8 ± 2.5 mmol/L red cells, respectively). As depicted in Table 3, after H-NaD treatment, the progressive reduction of MCV was coupled with a slight decrement of e[K\(^+\)]; in contrast, e[K\(^+\)] significantly increased, in the presence of a stable value of MCV, after L-NaD.

**Discussion**

In individuals with normal renal function, the increase of extracellular osmolality induced by effective osmoles, such as
sodium, glucose, amino acid, mannitol, and radiopaque media, causes a significant increment of plasma potassium (17–21). It has been hypothesized that in the presence of higher tonicity of the extracellular fluid (ECF), K⁺ moves out the intracellular fluid (ICF) by solvent drag (1,22); according to this hypothesis, as water is forced out of cells by the osmotic gradient, K⁺ will be entrained in the convective current and will exit cells in proportion to the membrane permeability. Alternatively, the increase in ECF and the decrease in ICF will change the K⁺/ICF/K⁺/ECF and Na⁺/ICF/Na⁺/ECF ratios, thus modifying the transmembrane potential or Na⁺-K-ATPase activity.

Although the hypertonicity-induced increase of p[K⁺] is usually of minor importance when renal function is preserved, the clinical impact of this phenomenon certainly grows in patients with renal impairment. We previously demonstrated that in moderate chronic renal failure, plasma tonicity is a specific determinant of K⁺ levels (8). In that study, a significant increase of p[K⁺] was detected in the presence of major increments of plasma tonicity, i.e., beyond the normal range of p[Na⁺] concentration. Of note, the phenomenon occurred despite the enhancement of the urinary excretion of K⁺ and was independent of the main mechanisms known to regulate the extrarenal homeostasis of this solute, such as acid-base balance, insulin, aldosterone, and adrenergic activity. The present study shows that in anuric patients, even modest changes in plasma tonicity, of a magnitude commonly encountered in clinical practice, can have relevant effects on the postdialysis levels of p[K⁺].

Because sodium is the major determinant of effective osmolality in blood and dialysis fluid, dialysate sodium concentration is the variable that can be more easily varied to change plasma tonicity in HD patients. Indeed, modification of NaD is a common therapeutic approach in these patients. In the past, both hypernatremic and hyponatremic dialyses have been used, the former to reduce intradialytic morbidity and the latter to obtain a better control of thirst and interdialytic weight gain. Recently, however, the variation of NaD has been restricted within the isotonic or “physiologic” range to avoid excessive alteration of plasma tonicity and the consequent detrimental effects, either chronic volume overload or poor tolerance to dialysis treatment (10,11). In this study, the small change of NaD resulted in p[Na⁺] levels that did not fall out of the normal range.

The imposed difference in plasma tonicity strikingly influenced the postdialysis K⁺ levels. The increase of p[K⁺] from T0 to T120 was significant only after the H-NaD treatment, whereas the L-NaD session led to a postdialysis increment of a small and not significant extent. Furthermore, as observed for p[Na⁺], such a difference persisted during the entire period of follow-up. Although patients were not monitored in our clinical research center during the interdialytic period, the higher p[K⁺] observed after H-NaD in the T24 h to T68 h period was probably unrelated to changes of nutritional intake as patients were asked not to vary the diet. Indeed, the nPCR value was comparable after the two sessions in the T0 to T68 h interval.

We analyzed the effect of tonicity on p[K⁺] in the absence of factors that interfere with K⁺ balance. The study was performed in nondiabetic patients who, besides the proven compliance to the diet, were not treated with any drug that modifies p[K⁺]; in addition, in both experimental sessions, K⁺ removal was similarly adequate. We can also exclude the influence of two factors that profoundly affect the relative ICF/ECF distribution of K⁺: insulin and acid-base balance (23). It is interesting that the increment of p[K⁺] was greater after the H-NaD treatment despite the higher values of plasma bicarbonate. The reason for the different p[HCO₃⁻] is not readily apparent; however, we hypothesize that in H-NaD, the presence of a higher amount of Na⁺ at the level of dialyzer may have determined a higher Na⁺ concentration gradient between dialysate and blood with enhanced diffusive transport of Na⁺ into blood and consequent proportional diffusion of HCO₃⁻ to maintain electroneutrality.

Plasma tonicity was therefore a primary determinant of the postdialysis changes of p[K⁺]. Aldosterone may have mediated this effect at least partially; its plasma levels were in fact significantly decreased at the T120 control after H-NaD, possibly because of the higher ECF volume. Nevertheless, the contribution of this hormone was minimal because a similar decline also was observed after L-NaD. We cannot exclude a role of the adrenergic tone as we did not measure the blood levels of catecholamines; however, previous studies in nondia-

**Table 2.** Blood pH and plasma levels of HCO₃⁻, insulin, and aldosterone immediately (T0) and 120 min (T120) after the end of soft hemodiafiltration at high (143 mmol/L, H-na D) and low (138 mmol/L, L-NaD) sodium dialysate concentration

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>HCO₃⁻ (mmol/L)</th>
<th>Insulin (mU/L)</th>
<th>Aldosterone (pg/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T0</td>
<td>T120</td>
<td>T0</td>
<td>T120</td>
</tr>
<tr>
<td>H-NaD</td>
<td>7.446</td>
<td>7.451</td>
<td>28.0ᵇ</td>
<td>29.0ᵇ</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.008)</td>
<td>(0.7)</td>
<td>(0.7)</td>
</tr>
<tr>
<td>L-NaD</td>
<td>7.447</td>
<td>7.448</td>
<td>26.3</td>
<td>27.5</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.006)</td>
<td>(0.4)</td>
<td>(0.5)</td>
</tr>
</tbody>
</table>

Values are mean ± SEM.
ᵃ p < 0.05 versus T0.
b p < 0.05 versus L-NaD.
lyzed renal patients have found that this system is not involved in the mechanism of the tonicity-related changes of \([K^+]_1\) (8,22). It is interesting that the greater postdialysis changes of plasma phosphate after H-NaD strengthen the hypothesis of the primary role of tonicity because the metabolism of this solute is certainly not affected by aldosterone, insulin, or adrenergic tone.

The present study indicates that the postdialysis increase of \([K^+]_1\) and the tonicity-induced hyperkalemia share the same pathophysiologic mechanism, i.e., the development of ICF/ECF osmotic gradients with the consequent proportional exit from the cells of water and \(K^+\). To confirm this hypothesis, we assessed the concurrent transcellular shift of water and \(K^+\). This evaluation was attained by measuring bioimpedance parameters, which are stable and reproducible in postdialysis (24), as well as the volume of erythrocytes and the intraerythrocyte \(K^+\) levels.

Previous studies have shown that two BIA-derived measures—Xc/R ratio and PhA, i.e., the angular transformation of the ratio Xc/R (16)—are reliable predictors of ICF/ECF water distribution in normal subjects and in nonrenal diseases (16,25). Furthermore, in a large population of HD patients, PhA has been demonstrated to correlate inversely with the extracellular water/total body water ratio (26). In the first 2 h after the H-NaD treatment, PhA markedly decreased, suggesting expansion of ECF at the expense of ICF; indeed, total body water did not change in postdialysis as patients were anuric and no beverage or food was allowed. The parallel decrease of MCV supports the hypothesis of an intra- to extracellular shift of water. More important, the shrinkage of red cells was associated with a decrement of e\([K^+]\), demonstrating a cell depletion of \(K^+\) secondary to the tonicity-induced exit of water after H-NaD.

At variance with the postdialysis period, \([K^+]_1\) was not influenced by tonicity in the course of dialysis treatment. A possible explanation for such a discrepancy is that the intra-dialytic \([K^+]_1\) levels are determined primarily by the diffusive removal of \(K^+\) (6).

In conclusion, this study provides the first evidence that even a moderate hypertonicity at the end of dialysis treatment determines a further increase of \([K^+]_1\) throughout the interdialytic period. The underlying mechanism is likely represented by the tonicity-induced redistribution of water and \(K^+\) from the intra- to the extracellular compartment.

Acknowledgments
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References

Access to UpToDate on-line is available for additional clinical information at http://www.jasn.org/