EFFECT OF DIALYSATE SODIUM CONCENTRATION ON FLUID GAIN IN CHRONIC HEMODIALYSIS PATIENTS

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Background and Aims: In clinical practice dialysate conductivity is typically set to 14 mS/cm. The aim of this study was to correlate the conductivity displayed on a dialysis machine panel and the dialysate sodium concentration [Na], and also to evaluate the effect of dialysate [Na] on patients’ interdialytic fluid gain.

Patient and Methods: A total of 339 patients dialyzed with the Althin system (Drake Willock System 1000 Single Patient Delivery System, Althin Medical, Inc; Portland, Oregon; N=56 machines), or the Toray system (Toray TR-321 Series Single-Patient Dialysis System, Toray Medical Co., Ltd. Tokyo, Japan; N=20 machines) were enrolled in this study. The dialysate [Na] was analyzed with Nova Electrolyte/Chemistry Analyzers (Nova CRT-13, Nova Biochemical, MA, US). Maintenance of machines was performed regularly according to the manufacturers’ guidelines.

Results: The conductivity measured by the Althin system was higher than that measured by the Toray system (14.13 ± 0.10 mS/cm vs 13.96 ± 0.12 mS/cm; p < 0.001). However, the dialysate [Na] was lower in the Althin system (141.5 ± 2.1 mEq/L vs 143.4 ± 0.28 mEq/L, p=0.009). Since the ratio of dialysate [Na] to conductivity was about 10, the difference between ten times conductivity and dialysate [Na] (10 × conductivity – [Na]) was greater in the Toray system (p < 0.001). The dialysate [Na] was significantly higher than pre-HD serum [Na] (p < 0.001) in both systems. The dialysate [Na] positively correlated not only with the conductivity in both machines, but also with the post-HD serum [Na] and the percentage of post HD serum [Na] increment. Multiple linear regression analysis showed the percentage of inter-dialytic body weight gain positively correlated to the patient’s serum albumin levels, dialysate [Na] and the pre-HD serum [Na].

Conclusions: The dialysate [Na] that we regularly used was higher than expected and led to a positive salt gain in chronic HD patients. These results suggest that regular calibration of dialysate [Na] with a sodium sensor analyzer is necessary to adjust optimal dialysate [Na]. (Acta Nephrologica 2007; 21: 128-134)

Key words: Chronic kidney disease, dialysate sodium, conductivity, hypervolemia

INTRODUCTION

In the previous hemodialysis (HD) practice, the dialysate sodium concentration [Na] was maintained at a low level so that sodium was removed by a simple concentration gradient. The dialysate [Na] was gradually elevated after the membrane’s resistance to transmembrane pressure improved. Currently convective transport is predominately applied for sodium removal during HD. For the prevention of intra-HD hypotension, in some instances, dialysate conductivity was arbitrarily elevated to about 15 mS/cm, or even higher in sodium-profiling HD. Although 138-140 mEq/L dialysate [Na] is considered acceptable in general practice, there is no firm consensus on the standard concentration of dialysate [Na] to be used for routine HD.

In the clinical practice plasma water [Na] is considered to represent the osmotically active solute concentration. The conductivity is a reflection the levels of these cations in the dialysate. For the sake of convenience, rather than dialysate [Na], we measured dialysate conductivity so that a specific sodium sensor was not necessary. In general, dialysate conductivity is calibrated when the dilution tank for the solution B preparation
was set up in the beginning and repeated this checkup yearly by the dialysis machine maintainers. Most dialysis centers do not examine dialysate [Na] regularly. The exact level of dialysate [Na] and its relation to the dialysate conductivity must be further clarified.

We conducted this study to analyze the HD dialysate [Na] by using Nova Electrolyte/Chemistry Analyzers and to evaluate the relationship between dialysate [Na] and conductivity shown on the panel in two different HD machines. We also examined the effect of dialysate [Na] on inter-dialysis fluid gain in patients.

MATERIALS AND METHODS

A total of 339 patients (162 males, 177 females; mean age at initiation of dialysis: 56 ± 13) were dialyzed on 76 dialysis machines. The etiologies of end-stage renal disease were attributed to chronic glomerulonephritis in 50% of patients, diabetic nephropathy in 37%, and others 13%. There was no sodium profiling program used in this study. The serum sodium concentrations were examined at both the beginning and immediately after the termination of the HD session. Two models of machines were used in our center: Drake Willock System 1000 Single Patient Delivery System (Althin system; Althin Medical, Inc, Portland, Oregon; \( N = 56 \)), and Toray TR-321 Series Single-Patient Dialysis System (Toray system; Toray Medical Co., Ltd. Tokyo, Japan; \( N = 20 \)). Maintenance of both machines was performed regularly according to manufacturers’ guidelines. One formula of dialysate (A-25 and BP-11, Hemodialysis Concentrates, Chi Sheng Chemical Co. Hsinchu, Taiwan) was used for all patients in this center. In concentrate A-25, a 3.8L plastic bottle contained a solution of sodium chloride (2946 mmol/L), calcium chloride dehydrate (46.3 mmol/L), magnesium chloride hexahydrate (18.2 mmol/L), acetic acid (147.6 mmol/L), and dextrose monohydrate (409.4 mmol/L). Concentrate BP-11, a bag of powder containing 1115 g sodium chloride and 3120 g sodium bicarbonate was diluted into 47.3 L of solution. The proportions for the final dilution were 1 part A-25: 1.83 parts BP-11: 34 parts reverse osmosis (RO) water. The accuracy of proportion for concentrate dilution in both systems was monitored by “conductivity” with impedance method. The conductivity of dialysate solution including sodium, potassium, calcium, and magnesium, was set at 14 mS/cm in both systems. The reference level of dialysate [Na] was 139.0 mEq/L. The calcium concentration in the dialysate was 3.0 mEq/L. The dialysate [Na], drawn from a dialysate port before entering the artificial kidney, was measured by Nova Electrolyte/Chemistry Analyzers (Nova CRT-13, Nova Biochemical, MA, US). In this study we correlated not only the dialysate [Na] with the conductivity in both systems, but also the dialysate [Na] with patient’s pre- and post-HD serum [Na]. The differences among the dialysate [Na], patients’ pre-HD and post-HD serum [Na] in both systems were also compared.

STATISTICAL ANALYSIS

Comparisons of continuous data were made by unpaired Student’s t-test. The relationship between dialysate [Na] and various parameters (conductivity, post-HD serum [Na], and the percentage of post-HD serum [Na] increment) were evaluated by simple lineal regression. Correlations between percentage of interdialytic body weight gain (% \( \Delta BW/dry \) weight) and serum albumin concentration, dialysate [Na], both pre- and post-HD serum [Na] were examined by using multiple regression analysis. The data were expressed as mean ± standard deviation. A p-value of less than 0.05 was considered statistically significant. Computations were performed with the SPSS 10.0 package for Windows (SPSS, Chicago, IL).

RESULTS

Compared to the Toray machine, the conductivity set by the Althin machine was significantly higher (14.13 ± 0.10 mS/cm vs. 13.96 ± 0.12 mS/cm; \( p < 0.001 \)), but the dialysate [Na] measured by Nova CRT-13 was lower for the Althin machine (141.5 ± 2.1 mEq/L vs. 143.4 ± 0.28 mEq/L, \( p = 0.009 \)).

Since the ratio of dialysate [Na] to conductivity was about 10, the difference between ten times conductivity and dialysate [Na] (10 × conductivity – [Na]) was greater for the Toray machines than the Althin machines (-0.24 ± 2.21 vs. -3.73 ± 2.58, \( p < 0.001 \)). The dialysate [Na] (mean 142.0 ± 2.4 mEq/L) presented as a normal distribution rather than a fixed value (Fig. 1).

The dialysate [Na] (Althin: 141.5 ± 2.1 mEq/L; Toray: 143.4 ± 2.9 mEq/L) were significantly higher than the pre-HD (Althin: 137.9 ± 3.5 mEq/L; Toray: 137.7 ± 3.4 mEq/L) and post-HD serum [Na] (Althin: 139.6 ± 2.2 mEq/L; Toray: 139.7 ± 1.8 mEq/L) in patients in both machines (Fig. 2). The dialysate [Na] was
Fig. 1. The dialysate sodium concentrations, with a mean of 142.0±2.4mEq/L, presented as a normal distribution in both machines rather than a fixed value.

Fig. 2. The dialysate sodium concentrations were significantly higher than the pre-HD and post-HD serum [Na] in patients on both machines (*: Student t test).
also positively correlated to the conductivity in both machines (Althin, r = 0.20; p = 0.03; Toray, r = 0.40; p = 0.009). Moreover, the dialysate [Na] showed a positive correlation to post-HD serum [Na] (r = 0.44, p < 0.001; Fig. 3) and the percentage of post-HD serum [Na] increment (% of post-HD serum [Na] – pre-HD serum [Na]/ pre-HD serum [Na]) (r = 0.27; p < 0.001; Fig. 4) but not to pre-HD serum [Na].

Multiple linear regression tests showed % ΔBW/dry weight positively correlated with the pre-HD albumin concentration, dialysate [Na] and pre-HD serum [Na] (Table 1).

**DISCUSSION**

Regarding 14 mS/cm in conductivity as 140 mEq/L in dialysate [Na], the main finding of this study is that measured dialysate [Na] (> 140 mEq/L) was higher than expected. Using the same formula, different HD machines yielded different dialysate [Na]. There was even variation within machines from the same system. This indicated that conductivity was a rather uneven monitoring for dialysate [Na].

Multiple linear regression tests showed % ΔBW/dry weight positively correlated with the pre-HD albumin concentration, dialysate [Na] and pre-HD serum [Na] (Table 1).

**Table 1. Correlation between inter-dialytic body weight gain to dry weight and various parameters of hemodialysis (HD) patients (multiple regression analysis; r=0.39, p<0.001)**

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>SE</th>
<th>p-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albumin (g/dL)</td>
<td>0.147</td>
<td>0.02</td>
<td>0.001</td>
<td>0.001 - 0.009</td>
</tr>
<tr>
<td>Dialysate [Na] (mEq/L)</td>
<td>0.086</td>
<td>0.000</td>
<td>0.099</td>
<td>0.000 - 0.001</td>
</tr>
<tr>
<td>Pre-HD serum [Na] (mEq/L)</td>
<td>-0.837</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.002 - 0.001</td>
</tr>
</tbody>
</table>

Dependent Variable: % of Δ body weight to dry weight
Abbreviation: [Na]: sodium concentration

and dialysate [Na] were noted between two systems. It signified the conductivity was a rather insensitive tool to estimate the dialysate [Na]. It seems to be indicative to regularly check dialysate [Na] by more accurate Nova CRT-13, rather than by traditional conductivity meter only.

It is well known that “hypotonic” dialysate causes muscle cramps and hypotension. For the prevention of intradialysis hypotension, we sometimes use sodium profiling to modify dialysate [Na]. This affects plasma sodium levels by diffusive sodium transport during the course of HD. Sodium profiling prevents osmotic disequilibrium, but also leads to excessive sodium accumulation. The resulting elevated sodium levels frequently lead to increased thirst, increased interdialytic fluid gain, and the development of hypervolemia and hypertension. Thus, we only used this procedure for patients with severe hypotension that could not achieve the target of the ultrafiltration rate. The patient’s serum [Na] was significantly lower in pre-HD than in post-HD states. This was apparently caused by the dilution effect of free water accumulated during the inter-dialysis period. Although the relatively hypotonic fluid removed during ultrafiltration plays a part, the back-diffusion of dialysate sodium into the blood stream may be also an important factor for the result of post-HD serum [Na] increment. By multivariate analysis, the dialysate [Na] was proved to be an independent factor that determined the interdialysis weight gain of HD patients. This means that the higher the levels of dialysate [Na], the more sodium influx into the blood stream of patients through the diffusion effect. We suggest that “hypernatric” dialysate, even in the range of 138-140 mEq/L typically used in the clinical practice,
Fig. 3. The dialysate sodium concentration showed a positive correlation to the post-hemodialysis serum sodium concentration ($r=0.44, p<0.001$).

Fig. 4. The dialysate sodium concentration showed a positive correlation to the percentage of post-hemodialysis serum sodium concentration increment (% post HD [Na] — pre HD [Na]/post HD [Na]) ($r=0.27; p<0.001$).
tends to cause excessive sodium load in uremic patients. In support of this, a report from Korea showed that positive sodium load occurred with time-averaged concentration of dialysate [Na] more than 137.8 mEq/L and that inter-dialytic weight gain increased in proportion to the time average concentration of dialysate [Na].

The blood [Na] measured by direct ionometry should be corrected for a Donnan factor of 0.967 (due to the negative charge of proteins) in order to determine the [Na] available for diffusion from the blood compartment. The gap between dialysate [Na] and the serum [Na] will become greater if the Gibbs-Donnan effect is considered, then the effect of back-diffusion of sodium ion into the circulation of uremic patients would be more significant.

Theoretically convective transport can remove most of the sodium from patients during HD. However, body weight gain was independently correlated to dialysate [Na], indicating that the back diffusion effect from the dialysate sodium is another important route for sodium load in HD patients. Significant body weight gain may lead to congestive heart failure and increased incidence of left ventricular hypertrophy. Lambie et al. found an improvement in interdialytic weight gain and blood pressure control when dialysate [Na] decreased to 130 mEq/L from 135 mEq/L. Several reports also found that reducing dialysate [Na] benefited volume control. Low dialysate [Na] leading to a reduction of blood pressure was found in peritoneal dialysis too.

Another factor causing relatively high dialysate [Na] (compared to patients’ pre-HD serum [Na]) in our center may be due to inaccurate calibration of the proportion between the BP-11 powder and RO water. Technically, solution BP-11 was prepared every day with a bag of powder diluted into 47.3 L of solution with RO water. This proportion scale was roughly set, under the basis of 14 mS/cm in conduction by the conduction meter, in the initial stage. No regular further accurate calibration was arranged. So we suggested regular monitoring of dialysate [Na] by applying CRT-13 analyzer is the best way to ensure accurate calibration.

Kenan et al. found that removal of sodium and fluid is a predictor of mortality in post-HD patients. They suggested that optimal dialysis should include sodium removal that is adequate to achieve normal volume homeostasis. Sodium flux from “hypermatric” dialysate negatively affects volume control in uremic patients. One study used bio-impedance techniques to show that the fluid gained between dialysis sessions mostly remains in the extracellular space. To avoid these complications, it is better to reduce the dialysate [Na] as much as possible. de Paula et al. suggested that dialysate sodium should be individualized to match the patient’s pre-HD serum [Na], so as to reduce unnecessary thirst, weight gain, and hypertension.

In conclusion, the present study gives information about the significantly higher level of dialysate [Na] in HD than we expected. Regular monitoring of the dialysate [Na] with an electrode biosensor allows for a better calibration. Dialysate [Na] significantly affected fluid gain in chronic dialysis patients. On the basis of without major complications, such as muscle cramps and intradialytic hypotension, relative decline of the dialysate [Na] is indicative for chronic HD patients, especially for those with hypervolemia.

REFERENCES


