Original Research Article

Evaluation of fluid status related parameters in hemodialysis and peritoneal dialysis patients: Clinical usefulness of bioimpedance analysis

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Abstract

Background and objective: Fluid overload is a common and serious problem that leads to severe complications in dialysis patients. We aimed to compare hydration status as measured with bioimpedance analysis (BIA) method in hemodialysis (HD) and peritoneal dialysis (PD) patients, as well as investigating the association between blood pressure, left ventricular mass index (LVMI) and hydration status.

Materials and methods: We examined 43 HD and 33 PD patients. Blood pressure was recorded. In each group, echocardiographic examinations were performed on all patients. Hydration status was assessed using multifrequency bioelectrical impedance analysis. Overhydration was defined as an overhydration (OH)/extracellular water (ECW) ratio of >0.15.

Results: The OH/ECW ratio was significantly higher in PD patients compared to post-HD patients. Overhydration was statistically more frequent in PD than in post-HD patients (30.3% vs. 11.6%, P = 0.043). Systolic blood pressure (SBP) in both post-HD and PD groups, and LVMI in the PD group were found to be significantly higher in overhydrated patients than non-overhydrated patients. In multiple linear regression analyses, increased OH/ECW ratio was independently associated with higher SBP and LVMI.

Conclusions: Fluid overload may be an even more prevalent and serious problem in PD patients. Overhydration is closely associated with increased blood pressure and LVMI. OH/ECW ratio, a derived parameter of fluid load measured by BIA, was a significant and independent determinant of SBP and LVMI.

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1. Introduction

Fluid overload is a common and serious problem that leads to severe complications in hemodialysis (HD) and peritoneal dialysis (PD) patients. Cardiovascular diseases (CVD) are the leading cause of morbidity and mortality in end-stage renal disease (ESRD) patients [1]. Volume and pressure overload have an important impact on development of cardiovascular disease. It is known that fluid overload is clearly associated with hypertension and left ventricular hypertrophy in this population. However, management of hypertension is difficult in dialysis patients, and many patients also have uncontrolled hypertension despite the use of antihypertensive drugs [2]. Moreover, better control of blood pressure requires accurate fluid balance in most dialysis patients.

In addition, it is also shown that fluid overload is associated independently and significantly with mortality in dialysis patients [3,4]. Euvolemia is most commonly evaluated based on unreliable clinical signs, such as changes in body weight, edema and blood pressure, in daily clinical practice by the dialysis provider, but those may lead to misinterpretations. Therefore, more reliable, practical and objective methods are extremely needed. In this respect, bioelectrical impedance analysis (BIA) has been proposed for the assessment of hydration status parameters.

BIA is a simple, safe, novel, rapid, noninvasive and promising method that can be used to determine hydration status in patients on dialysis therapy [5-8]. BIA method has gained increasing popularity in recent years. Different from other methods, it allows quantification of intracellular and extracellular volumes [9]. The Body Composition Monitor (BCM, Fresenius Medical Care, Germany) is a bio-impedance spectroscopy device and has been well validated by gold standard methods for clinical use [5,6].

In the present study, we aimed to compare hydration status, as measured with BIA method, in HD and PD patients in a single center, as well as investigating the association between blood pressure, left ventricular mass index (LVMI) and hydration status.

2. Materials and methods

2.1. Patients

This cross-sectional study design included 43 stable chronic hemodialysis and 33 stable chronic ambulatory peritoneal dialysis (CAPD) patients treated and followed up in the same center. The Local Human Research Ethics Committee approved the study protocol, and informed consent was obtained from all patients at the time of study enrollment.

The exclusion criteria were as follows: (1) patients with ejection fraction <55%, (2) hemodynamically unstable patients, (3) patients who had limb amputation, pacemakers, or metallic intravascular devices, or any malignant disease or pregnancy, (4) patients who had been receiving diuretic treatment.

The HD patients received dialysis 3 times/week, using 1.6 m² surface area high-flux polysulphone dialyzers (Fresenius, Bad Homberg, Germany) and bicarbonate-based dialysate (glucose 1 mmol/L, Na⁺ 140 mEq/L, HCO₃⁻ 32 mEq/L, K⁺ 2.0 mEq/L, Ca²⁺ 1.25 mmol/L, Mg²⁺ 0.5 mEq/L). Of the 33 patients on CAPD, icodextrin was administered in 65% of them.

Patients’ demographics were obtained from both the patients’ registries and the patients themselves.

2.2. Measurements

24-h urine samples were collected to determine urine volume. Weight was measured after dialysis. Body mass index (BMI) was calculated as the ratio weight/height² (kg/m²) and body surface area (BSA) was calculated from weight and height.

Systolic (SBP) and diastolic blood pressures (DBP) were measured 30 min after the end of hemodialysis using an air manometer at the time of BIA investigation and are presented as three consecutive measurements taken at 5-min intervals. Blood pressures were measured in PD patients with empty abdomen using the same method.

Blood samples were collected from all patients for biochemical and hematological parameters on the same day as the BIA measurements.

2D-guided M-mode echocardiography (Vivid 7, GE Healthcare, Horten, Norway) with a 3.5 MHz transducer was performed with empty abdomen in all PD patients, and after the hemodialysis session in all HD patients, by the same cardiologist according to the recommendation of the American Society of Echocardiography on the same day as the BIA examination [10]. Left ventricular systolic function was assessed by left ventricular ejection fraction (LVEF). Left ventricle internal diastolic diameter (LVIDd), diastolic posterior wall thickness (PWT) and interventricular septum thickness (IVS) were measured. Left ventricular mass (LVM) was calculated using the equation described by Devereux [11].

\[
LVM = 1.04 \times \left[ (LVIDd + PWT + IVS)^3 - LVIDd^3 \right] - 13.6 \text{ g}
\]

slVM index (LVMI) was calculated by dividing LVM by BSA.

A multifrequency BIA device (Body Composition Monitor, BCM, Fresenius Medical Care D GmbH), which measures 50 different frequencies from 5 to 1000 kHz, was used to assess hydration status. All measurements were performed by the same operator. BIA was performed with empty abdomen in PD patients, and 30 min after the midweek dialysis session in HD patients. The following parameters were obtained: overhydration (OH), extracellular water (ECW), intracellular water (ICW), total body water (TBW) in liters (L), ECW/TBW, ECW/ICW, and OH/ECW ratio. We used OH/ECW ratio as an indicator of fluid status. Overhydration was defined as an OH/ECW ratio greater than 0.15 according to previous reports [3,12]. Patients were divided into two groups: overhydrated (OH/ECW >0.15) and nonoverhydrated (OH/ECW ≤0.15).

2.3. Statistical analysis

Data analyses were performed using Statistical Package for Social Sciences (SPSS), Version 18.0 for Windows (SPSS Inc., Chicago, IL, USA). Normally distributed variables are presented using means and standard deviations. The Student t test was used to compare the means of the continuous variables with normal distribution for related and independent samples. The proportions of patients with overhydration are presented
using cross tabulations between groups. The chi-square test was used to compare these proportions in different groups. The Pearson correlations were used for simple regression analysis. A multiple linear regression analysis was performed to identify independent predictors of SBP and LVMI. P values less than 0.05 were considered statistically significant.

3. Results

A total of 76 dialysis patients (43 post-HD and 33 PD) were enrolled in the study. The baseline demographic, clinical, relevant laboratory data and BIA parameters are presented in Table 1.

PD patients were younger than HD patients. There were no significant differences in gender distribution and dialysis vintage between groups. The patients on PD had significantly higher residual urine and lower percentage of diabetes than patients on HD. SBP and DBP were lower in post-HD compared to PD patients. Left ventricular ejection fraction was significantly lower in the PD group than in the post-HD group.

Regarding the derived parameters of BIA, OH and OH/ECW ratios were higher in PD group compared to the post-HD group. Overhydration based on OH/ECW was statistically more frequent in PD than in post-HD patients (30.3% vs. 11.6%, P = 0.043).

Five patients in the post-HD group and 10 patients in the PD group were significantly overhydrated (OH/ECW >0.15).

Overhydrated patients had significantly higher SBP in both post-HD and PD groups (HD: 123.33 ± 19.14 vs. 109.86 ± 13.46, P = 0.038; PD: 148.88 ± 22.60 vs. 122.50 ± 21.11, P = 0.004; Fig. 1A) than non-overhydrated patients. However, there were no significant differences in terms of diastolic blood pressure between overhydrated patients and non-overhydrated patients both in the post-HD and the PD groups (Fig. 1B). Compared to non-overhydrated patients, overhydrated patients had significantly higher levels of LVMI in the PD group (151.23 ± 15.10 vs. 99.50 ± 27.24, P < 0.001; Fig. 1C).

There were significant positive correlations between OH/ECW and SBP, DBP, OH, ECW, ECW/TBW, ECW/ICW, and LVMI and negative correlations with albumin and EF (Table 2).

Furthermore, we modeled a stepwise linear regression analysis to define the independent determinants of SBP and LVMI. PD as dialysis modality and increased OH/ECW ratio were independently associated with higher SBP (Table 3). For LVMI, OH/ECW (greater overhydration) was the independent predictor (Table 4).

### Table 1 - Demographic, clinical, relevant laboratory data and bioimpedance parameters in hemodialysis vs. peritoneal dialysis patients.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>post-HD (n = 43)</th>
<th>PD (n = 33)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>51.8 ± 15.8</td>
<td>38.6 ± 15.8</td>
<td>0.001</td>
</tr>
<tr>
<td>Gender, M/F, n</td>
<td>13/30</td>
<td>11/22</td>
<td>0.77</td>
</tr>
<tr>
<td>Dialysis vintage, months (months)</td>
<td>70.6 ± 39.8</td>
<td>75 ± 51.5</td>
<td>0.79</td>
</tr>
<tr>
<td>Diabetes, %</td>
<td>25.6</td>
<td>3</td>
<td>0.008</td>
</tr>
<tr>
<td>Residual urine, mL/day</td>
<td>29 ± 9</td>
<td>479 ± 70</td>
<td>0.001</td>
</tr>
<tr>
<td>Na, mEq/L</td>
<td>136 ± 2</td>
<td>135 ± 2</td>
<td>0.131</td>
</tr>
<tr>
<td>Albumin, g/dL</td>
<td>3.3 ± 0.4</td>
<td>3.1 ± 0.4</td>
<td>0.202</td>
</tr>
<tr>
<td>Hemoglobin, g/dL</td>
<td>10.9 ± 1.4</td>
<td>12.8 ± 16.6</td>
<td>0.335</td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td>111 ± 14</td>
<td>129 ± 24</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DBP, mmHg</td>
<td>71 ± 9</td>
<td>83 ± 15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>OH, L</td>
<td>0.6 ± 1.0</td>
<td>1.3 ± 1.2</td>
<td>0.011</td>
</tr>
<tr>
<td>TBW, L</td>
<td>28.5 ± 6.9</td>
<td>27.4 ± 5.7</td>
<td>0.52</td>
</tr>
<tr>
<td>ECW, L</td>
<td>13.2 ± 3.1</td>
<td>13.4 ± 2.8</td>
<td>0.95</td>
</tr>
<tr>
<td>ICW, L</td>
<td>15.2 ± 4.3</td>
<td>14.4 ± 3.0</td>
<td>0.34</td>
</tr>
<tr>
<td>ECW/ICW</td>
<td>0.9 ± 0.1</td>
<td>0.9 ± 0.1</td>
<td>0.35</td>
</tr>
<tr>
<td>ECW/TBW</td>
<td>0.4 ± 0.05</td>
<td>0.4 ± 0.8</td>
<td>0.23</td>
</tr>
<tr>
<td>OH/ECW</td>
<td>0.04 ± 0.07</td>
<td>0.09 ± 0.09</td>
<td>0.009</td>
</tr>
<tr>
<td>OH/ECW &gt;0.15, %</td>
<td>11.6</td>
<td>30.3</td>
<td>0.043</td>
</tr>
<tr>
<td>LVMI/g/m²</td>
<td>106 ± 24</td>
<td>113 ± 33</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

SBP, systolic blood pressure; DBP, diastolic blood pressure; OH, overhydration; ECW, extracellular water; ICW, intracellular water; TBW, total body water; LVMI, left ventricular mass index; LVEF, left ventricular ejection fraction; post-HD, posthemodialysis; PD, peritoneal dialysis.

![Fig. 1](image) - Comparison of systolic blood pressure (SBP) (A), diastolic blood pressure (DBP) (B), and left ventricular mass index (LVMI) (C) between overhydrated and nonoverhydrated patients in posthemodialysis (post-HD) and peritoneal dialysis (PD) groups.
### Table 2 – Correlations between the overhydration/extracellular water ratio and study parameters.

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>−0.016</td>
<td>0.891</td>
</tr>
<tr>
<td>Albumin</td>
<td>−0.291</td>
<td>0.011</td>
</tr>
<tr>
<td>SBP</td>
<td>0.519</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DBP</td>
<td>0.442</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>OH</td>
<td>0.966</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ECW</td>
<td>0.217</td>
<td>0.059</td>
</tr>
<tr>
<td>Icw</td>
<td>−0.227</td>
<td>0.051</td>
</tr>
<tr>
<td>TBW</td>
<td>0.029</td>
<td>0.805</td>
</tr>
<tr>
<td>ECW/TBW</td>
<td>0.389</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ECW/ICW</td>
<td>0.597</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVMI</td>
<td>0.562</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EF</td>
<td>−0.338</td>
<td>0.003</td>
</tr>
</tbody>
</table>

SBP, systolic blood pressure; DBP, diastolic blood pressure; OH, overhydration; ECW, extracellular water; ICW, intracellular water; TBW, total body water; LVMI, left ventricular mass index; EF, ejection fraction.

### 4. Discussion

Fluid overload is frequently present in dialysis patients and leads to adverse clinical outcomes such as hypertension [13], cardiovascular diseases [14,15] and higher mortality [16]; thus, keeping dialysis patients euvolemic is essential [12]. Despite the fact that fluid overload is a preventable or treatable condition, managing fluid balance and achieving true dry weight is still major challenge in both HD and PD patients. The indices obtained from BIA are useful for the assessment of fluid status [17].

The different dialysis modalities, such as peritoneal dialysis and hemodialysis, have different effects on fluid volume control [4]. Although PD is believed to provide better fluid control than HD due to its continuous ultrafiltration and the fact that residual renal function is better maintained [18,19], fluid overload is a quite common problem in PD patients [20]. In the EuroBCM study conducted in six European countries on 639 PD patients, Van Biesen et al. recently reported that severe fluid overload was present in 25.2% of the study population [21]. By BIA measurement, Devolder et al. revealed that the ratio of OH/ECW was higher in the PD patients compared to post-HD patients [12]. In agreement with the findings of Devolder et al., our study has shown that the ratio of OH/ECW was significantly higher in PD patients compared to post-HD patients. Overhydration based on OH/ECW was statistically more frequent in PD than post-HD patients (30.3% vs. 11.6%, P = 0.043).

The findings of this study indicate that fluid overload may be an even more common and serious problem in PD patients compared to HD patients. One of the most important reasons might be that hemodialysis provides easier and more efficient control of extracellular volume overload [22]. Another reason might be that physicians evaluate fluid status of PD patients less frequently than HD patients [23]. Given that fluid overload seems to be frequent in both PD and post-HD patients, it is clear that current methods are insufficient in volume control. In this respect, bioimpedance analysis may be helpful to overcome this issue.

Hypertension is very frequent in ESRD patients and leads to several adverse clinical outcomes [22]. While the pathogenesis of hypertension is multifactorial, fluid overload is the leading cause in dialysis patients [23]. It has been revealed in many studies that increased fluid overload is basically in an extracellular fluid compartment that results in hypertension [24,25]. Chen et al., in a prospective study including 121 HD and 84 PD patients, observed that all patients with overhydration had hypertension in both the hemodialysis and peritoneal dialysis groups [26]. Another study by Yao et al. reported that overhydrated patients assessed by BIA measurement had higher SBP than non-overhydrated ones, in both the PD and the HD patients [27]. Compatible with the findings of Yao et al., overhydrated patients in our study had significantly higher SBP compared to non-overhydrated patients in both post-HD and PD groups. Another important finding of the present study is that an increased OH/ECW ratio and PD as dialysis modality are independently associated with higher SBP in multiple linear regression analyses.

Our study contributes strong support to the previous studies by demonstrating the close association between hydration status and blood pressure. Given the importance of hypertension as the main cause of morbidity and mortality in the dialysis population [23], one of the main goals is to achieve a normotensive state. Although its utility was not investigated in our study design, we believe that BIA can help to distinguish dialysis patients whose hypertension is volume-dependent or non-volume dependent, and can also prevent unnecessary antihypertensive agent using.

### Table 3 – Stepwise multiple linear regression analyses for the independent determinants of systolic blood pressure.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Beta coefficient</th>
<th>95% CI</th>
<th>Standardized Beta coefficient</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modality (HD vs. PD)</td>
<td>−9.31</td>
<td>−17.52 to −1.09</td>
<td>−0.225</td>
<td>0.027</td>
</tr>
<tr>
<td>OH/ECW</td>
<td>120.14</td>
<td>72.18 to 168.10</td>
<td>0.497</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Constant</td>
<td>116.01</td>
<td>72.18 to 168.10</td>
<td>0.497</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CI: confidence interval. Model: P < 0.001; R² = 0.371.

### Table 4 – Stepwise multiple linear regression analyses for the independent determinants of LVM.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Beta coefficient</th>
<th>95% CI</th>
<th>Standardized Beta coefficient</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>OH/ECW</td>
<td>97.17</td>
<td>126.77 to 254.61</td>
<td>0.568</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CI: confidence interval. Model: P < 0.001; R² = 0.323.

Included variables: OH/ECW, albumin, gender (male vs. female), HD vs. PD, SBP and DBP.
Left ventricular hypertrophy (LVH) is very prevalent in ESRD patients at the start of dialysis [28,29]. Increased left ventricular mass (LVM) is associated with mortality and cardiovascular morbidity in this patient population [30]. Despite the fact that several factors, such as anemia, hyperparathyroidism, uremia and malnutrition, play roles in the development of LVH, hypertension and fluid overload are the main causes. The relationship between fluid overload and LVH was revealed in previous reports [13,15]. Consistent with the results of Yao et al. [27], our study has shown that increased an OH/EW ratio was independently associated with higher LVM. Moreover, we found that overhydrated patients had significantly higher levels of LVM in the PD groups compared to non-overhydrated patients. These findings once again emphasize the importance of volume control for cardiac protection in dialysis patients.

5. Conclusions

We suggest that fluid overload may be an even more prevalent and serious problem in PD patients compared to post-HD patients. Once again, our results show that fluid overload is closely associated with increased blood pressure and LVM index. OH/EW, a derived parameter of fluid load measured by BIA, was a significant and independent determinant of SBP and LVM.

Conflict of interest

The authors declare no conflicts of interest.

REFERENCES


