Multifrequency bioimpedance in assessment of dry weight in haemodialysis


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•Participated only in Study 1; **Participated only in Studies 1 and 2; ***Participated only in Study 3

Abstract. The use of multifrequency bioimpedance (MFB) for determination of dry weight (DW) in haemodialysis (HD) patients was evaluated in three studies. In Study 1, the fluid state [total body water (TBW) and extracellular volume (ECV)] was measured by MFB in 82 normotensive patients, 41 hypertensive patients and in 30 healthy subjects. TBW and ECV were expressed as per cent of body weight (BW). In Study 2, DW of five hypertensive HD patients was gradually decreased during 3 months and ECV (MFB) and blood pressure (48 h ambulatory blood pressure monitoring) were measured at the beginning and end of study. In Study 3, we measured the fluid status repeatedly by MFB and the diameter of the inferior vena cava (DIVC) by ultrasound before, during and 2 h post-HD.

In Study 1, the hypertensive patients had significantly greater TBW (P<0.05) than the normotensive patients before (50.3 ± 6.5% vs 47.6 ± 5.8%) and after HD (48.8 ± 7.8% vs 45.7 ± 6.4%) and after HD (P<0.001) before (29.4 ± 3.6% vs 26.8 ± 3.5%) and after HD (27.0 ± 4.0% vs 24.6 ± 3.5%), Post-HD ECV in the normotensive patients was similar to that in the healthy subjects. In Study 2, more efficient ultrafiltration resulted in reduction of BW and ECV along with a decrease in blood pressure and need for antihypertensive medication. In Study 3, both ECV and DIVC decreased following the removal of fluid during HD. ECV maintained stable values during the post-HD period, unlike DIVC which increased significantly (P<0.005) due to refilling from the interstitial space.

We conclude that MFB is an appropriate non-invasive method for DW determination, which is highly reproducible and technically simple to use.

Key words: dry weight; extracellular volume; haemodialysis; diameter of inferior vena cava; multifrequency bioimpedance; total body water

Introduction

Chronic renal failure patients treated with maintenance haemodialysis (HD) retain salt and water in the interdialytic period, which has to be removed by ultrafiltration during the HD procedure to prevent progressive fluid accumulation with oedema formation, hypertension, and cardiac failure. In clinical dialysis it is essential to define for each patient the so-called dry weight (DW), i.e. the body weight (BW), representing normohydration, which the patient should attain at the end of HD. The evaluation of DW is generally made from clinical observations of BW changes, congestion, oedema, blood pressure and pulmonary X-ray. However, the evaluation of DW on clinical grounds is not very accurate.

Among the more objective methods, tracer dilution techniques are fairly precise, but they are far too complicated, time-consuming and expensive for routine clinical use. Some markers proposed for assessment of hydration state in HD are the diameter of the inferior vena cava (DIVC) measured by ultrasound [1], the plasma atrial natriuretic peptide (ANP) [2,3], and cyclic guanine monophosphatase (cGMP) [4]. However, these mainly reflect the state of hydration in the intravascular space and the volume of this space is not constant due to refilling from the interstitial space [5]. Moreover, both DIVC and ANP depend not only on the fluid state, but are influenced by cardiac performance [6] and also interactions with other hormonal systems [7].

Multifrequency bioimpedance (MFB), by which it is possible to distinguish between intracellular and
Bioimpedance and dry weight extracellular (ECV) spaces, was recently introduced for assessment of DW of HD patients by De Vries et al. [8]. It was demonstrated that MFB is particularly useful for assessment of DW in hypertensive HD patients. In this communication we describe the application of MFB and especially of a new device, Xitron (Xitron Tech, USA), in the assessment of DW in normotensive and hypertensive HD patients. This device has been recently validated by us [9,10] and by Ho et al. [11].

Subjects and methods

Study 1

One hundred and twenty-three patients (70 male, 53 female) from four large dialysis centres (Huddinge University Hospital and Sophia Hospital, Stockholm Sweden, Centre de Rein Artificial, Tassin, France, University Hospital, Prague, Czech Republic) were investigated by MFB before and after HD procedure (Table 1). The patients were divided in two groups: hypertensive (n = 41) and normotensive (n = 82). Predialysis systolic blood pressure of >150 mmHg and diastolic of >95 mmHg was used for definition of the hypertensive group. All hypertensive patients were treated with one or more antihypertensive drugs. Thirty non-matched healthy normotensive volunteers (11 male and 19 female) were used as controls (Table 2).

Study 2

Five HD patients (three male, two female; mean age 55 ± 13 years) considered by the clinicians to have ‘dialysis-resistant’ hypertension were observed over a period of 3 months, during which the DW was gradually lowered by intensified ultrafiltration and reduction of the dietary sodium intake. MFB and 48 h ambulatory blood pressure monitoring were performed before and at the end of the 3 month period. All patients were initially treated with two or more antihypertensive drugs. The antihypertensive treatment was gradually tapered or stopped when appropriate.

Study 3

DIVC and ECV were measured simultaneously in eight stable chronic HD patients (five male, three female; mean age 56 ± 11 years) using ultrasound and MFB during HD lasting 3 h and 2 h after HD. During this period the patients were kept in supine position, fluid and food intake was restricted to 300–400 g, and no infusions were administered. All vasoactive medications were stopped 48 h prior to the study.

Bioimpedance technique

An MFB device, Xitron 4000B (Xitron Tech, USA), was used. Fifty logarithmic space frequencies (5 kHz to 500 kHz) were applied wrist to ankle. A software program provided by the producer was used in computing TBW and ECV [11].

Ultrasound technique

DIVC was measured in expiration in subcostal orthogonal projection and ECG was monitored simultaneously as described elsewhere [1].

Blood pressure monitoring

Spacelab monitor 90207 was used. The monitoring was performed over 48 h, starting 20 min prior to the HD procedure. Measurements were performed every 20 min during the day and every 60 min during the night.

Statistical analysis

All data are presented as mean ± standard deviation. Paired and unpaired t-tests were used when appropriate. Values of P<0.05 were considered as significant.

Table 1. Age, predialysis and postdialysis body weight, and height of normotensive and hypertensive patients and the control group in Study 1

<table>
<thead>
<tr>
<th></th>
<th>Normotensive patients</th>
<th>Hypertensive patients</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>64 ± 13c</td>
<td>58 ± 14bd</td>
<td>41 ± 10</td>
</tr>
<tr>
<td>Body weight before haemodialysis (kg)</td>
<td>69.3 ± 14.8</td>
<td>65.7 ± 11.3d</td>
<td>72.9 ± 10.3</td>
</tr>
<tr>
<td>Body weight after haemodialysis (kg)</td>
<td>66.4 ± 14.7</td>
<td>63.9 ± 10.7c</td>
<td>72.9 ± 10.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166.5 ± 10.9</td>
<td>169.5 ± 9.0</td>
<td>170.0 ± 10.0</td>
</tr>
<tr>
<td>Systolic blood pressure before haemodialysis (mmHg)</td>
<td>134 ± 23</td>
<td>169 ± 22f</td>
<td>88 ± 11e</td>
</tr>
<tr>
<td>Diastolic blood pressure before haemodialysis (mmHg)</td>
<td>73 ± 11</td>
<td>88 ± 11e</td>
<td>88 ± 11e</td>
</tr>
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</table>

* P<0.0001 vs controls; b P<0.025 vs normotensive; c P<0.05 vs controls; d P<0.0025 vs controls; e P<0.0001 vs normotensive.

Table 2. Total body water (TBW) and extracellular volume (ECV) (in % of body weight) of normotensive and hypertensive patients and the control group in Study 1

<table>
<thead>
<tr>
<th></th>
<th>Normotensive</th>
<th>Hypertensive</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>%TBW before haemodialysis</td>
<td>47.6 ± 5.8</td>
<td>50.3 ± 6.5a</td>
<td>48.1 ± 5.0</td>
</tr>
<tr>
<td>%TBW after haemodialysis</td>
<td>45.7 ± 6.4</td>
<td>48.8 ± 7.8a</td>
<td>48.1 ± 5.0</td>
</tr>
<tr>
<td>%ECV before haemodialysis</td>
<td>26.8 ± 3.5a</td>
<td>29.4 ± 3.6d</td>
<td>25.4 ± 2.3</td>
</tr>
<tr>
<td>%ECV after haemodialysis</td>
<td>24.6 ± 3.5</td>
<td>27.0 ± 4.0d</td>
<td>25.4 ± 2.3</td>
</tr>
</tbody>
</table>

* P<0.05 vs normotensive; b P<0.05 vs controls; c P<0.001 vs normotensive; d P<0.0001 vs controls.
Results

Study 1

As demonstrated in Table 2, TBW was significantly greater in the hypertensive than in the normotensive group both before and after HD. In the normotensive HD patients predialysis ECV was significantly greater than ECV in the controls, but postdialysis ECV was similar to the controls. The hypertensive patients had greater pre- and postdialysis ECV than the normotensive patients.

Study 2

At the end of the 3 month period, DW, ECV and blood pressure decreased (Table 3). The antihypertensive medication was discontinued in all but one patient, in whom antihypertensive therapy was reduced.

Study 3

At the end of HD, BW decreased from 74.1 ± 10.5 to 72.4 ± 9.4 kg (P < 0.001); DIVC and ECV also decreased significantly (P < 0.0001 and P < 0.0025, respectively). During 2 h post-HD, DIVC increased again (P < 0.0025) compared to immediately after HD, but ECV remained stable (Fig. 1). According to DIVC (normal range 8–11 mm/m²), three patients were hypovolaemic and five normovolaemic at the end of HD procedure. After 2 h, two patients were hypervolaemic and six normovolaemic.

Discussion

Based on isotope dilution measurements, TBW in normal humans is generally considered to be about 55–60% of BW and ECV (by 35SO4 dilution) to be about 20% of BW. Measured by MFB, TBW was 48% of BW and ECV was 25% of BW in the healthy controls, i.e. the method as applied appears to systematically underestimate TBW and overestimate ECV. It should also be emphasized that expressing the body water volumes as per cent of BW only gives a crude evaluation of the hydration state, since the body composition may vary considerably between different individuals due to variation in body fat, cellular mass and bone mineral mass, which may be related to, among others, age, gender and nutritional status. In spite of these methodological errors and shortcomings, MFB seems to provide meaningful information regarding the hydration state in the groups of HD patients investigated.

Measured by MFB, the normotensive HD patients had an average postdialysis ECV of about 25% of BW, i.e. similar to the controls, whereas the hypertensive HD patients had about 10% greater postdialysis ECV than the controls and the normotensive patients. This is in keeping with the supposition that control of ECV (and body sodium) is crucial for control of blood pressure in HD patients. It should be pointed out that the predialysis ECV was significantly increased compared with the controls not only in the hypertensive

Table 3. Changes in dry weight, postdialysis extracellular volume, systolic and diastolic blood pressure (48 h automatic monitoring) in Study 2

<table>
<thead>
<tr>
<th></th>
<th>Start of study</th>
<th>3 months later</th>
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<tbody>
<tr>
<td>Dry weight (kg)</td>
<td>72.7 ± 14.9</td>
<td>70.7 ± 13.6*</td>
</tr>
<tr>
<td>Extracellular volume (l)</td>
<td>19.2 ± 4.4</td>
<td>17.8 ± 3.5*</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>158 ± 23</td>
<td>139 ± 11</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>95 ± 16</td>
<td>84 ± 8</td>
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* P < 0.05.
but also in the normotensive group. This accords with the clinical observation that interdialytic fluid accumulation does not cause marked blood pressure elevation provided that the patient is brought to normohydration at the end of HD by appropriate ultrafiltration [12,13]. The impact of the hydration state for blood pressure control was confirmed by the results of Study 2, which demonstrated that HD patients considered to have 'dialysis-resistant' hypertension were overhydrated and that reducing the post-HD ECV by more efficient ultrafiltration resulted in normalization of blood pressure. This study demonstrates the utility of MFB for repeated determinations of the hydration status in individual patients.

Measurement of DIVC by ultrasound has been proposed to be a valid method for assessment of the degree of hydration in HD patients. However, we have shown earlier that changes in DIVC parallel changes in blood volume and that an equilibration period of at least 2 h is required before DIVC stabilizes post-HD due to refilling of the vascular compartment from the interstitial space [5]. In Study 3, we compared DIVC and MFB and observed that MFB showed stable values over 2 h post-HD, suggesting that the fluid shifts between ECV and the intracellular volume were negligible and that measurements made immediately after HD reflect the degree of hydration. In contrast, DIVC increased during the postdialytic period due to plasma refilling, implying that measurements performed immediately after HD may underestimate the degree of hydration.

In conclusion, MFB is a non-invasive method for measuring TBW and ECV, which is highly reproducible and technically simple to use. It appears to be a valuable tool for assessment of dry weight in HD patients, and may be especially suitable for repeated determinations in the same patient followed over time.

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References