Impact of Hydration and Nutrition Status on the Watson Formula in Peritoneal Dialysis Patients

Urea clearance (Kt/V urea), adjusted for total body water (TBW) using the Watson formula (TBW$_{\text{Watson}}$), is widely used to guide peritoneal dialysis (PD) prescription and to ensure dialysis adequacy. The impact of body composition on the determination of TBW$_{\text{Watson}}$ is well established, but the effect of hydration and nutrition status on TBW$_{\text{Watson}}$ is not understood. We therefore studied the effects of hydration and nutrition status on TBW$_{\text{Watson}}$ in PD patients.

Our study enrolled 195 PD patients and 33 healthy control subjects. Multiple-frequency bioelectrical impedance spectroscopy (MF-BIS) was used to measure TBW, and the result was compared with TBW$_{\text{Watson}}$. Patients were divided into three groups according to their degree of overhydration [$\Delta$hydration status (OH) in liters]: normally hydrated group (OH: <2.0 L), mildly overhydrated group (OH: 2.0 – 4.0 L), and severely overhydrated group (OH: >4.0 L).

Compared with MF-BIS, the Watson formula overestimated TBW in normally hydrated patients, but underestimated TBW in severely overhydrated patients. In addition, of the normally hydrated patients, 22 were malnourished by subjective global assessment, and the TBW$_{\text{Watson}}$ overestimation was much greater in them than in the well-nourished patients.

Our study suggests that hydration and nutrition status both strongly affect TBW$_{\text{Watson}}$ in PD patients.

Key words
Bioimpedance, hydration status, nutrition status, Watson formula

Introduction
Urea clearance (Kt/V urea) is corrected for patient size by using total body water (V), where V is determined by anthropomorphic equations such as the Watson formula, which is recommended by many national and international guidelines (1–3). Some earlier studies suggested that the Watson formula can be affected by body composition, comorbidity, and ethnicity (4–8), and that the differences can lead to differences between “true total body water” and “calculated total body water,” thereby affecting the estimated Kt/V and the delivered dialysis dose. However, the impact of hydration and nutrition status on the accuracy of estimated total body water using the Watson formula (TBW$_{\text{Watson}}$) remain to be determined. We therefore used multi-frequency bioimpedance spectroscopy (MF-BIS) and nutrition status as assessed by subjective global assessment (SGA) to examine the effects of hydration and nutrition status on the estimation of TBW$_{\text{Watson}}$ in stable adult peritoneal dialysis (PD) outpatients.

Methods
This cross-sectional study enrolled 195 stable continuous ambulatory PD outpatients and 33 healthy control subjects. Based on volume measurements determined by MF-BIS (BCM: Fresenius Medical Care, Bad Homburg, Germany), patients were grouped according to their degree of overhydration [$\Delta$hydration status (OH) in liters]: normally hydrated (<2.0 L), mildly overhydrated (2.0 – 4.0 L), and severely overhydrated (>4.0 L).

The MF-BIS analysis was performed with the patient in supine position to ensure equilibration of fluid. The values for OH, extracellular water (ECW), intracellular water (ICW), TBW, and ECW/ICW ratio were then recorded. Overhydration refers to the difference between the normally expected ECW and
the measured ECW. Normal ECW can be determined using integrated MF-BIS software (Fresenius Medical Care) for a given weight and body composition (9). In addition to using MF-BIS to measure TBW, we also calculated $TBW_{\text{Watson}}$ as recommended by clinical guidelines (2).

The SGA was performed by one dedicated trained dietician in our program. Because of the low number of stable outpatients characterized as SGA grade C in our study, patients scored as grades B and C were evaluated together as “malnourished.”

Results are expressed as mean ± standard deviation for parametric continuous data, as median and interquartile range for nonparametric continuous data, and as frequencies and percentages for categorical data. The statistical analysis was performed using the SPSS for Windows software application (version 16.0: SPSS, Chicago, IL, U.S.A.). The agreement of TBW by MF-BIS and by the Watson formula was analyzed by the Bland–Altman method (10) using the MedCalc software application (version 12: MedCalc Software, Mariakerke, Belgium). All tests were two-sided and $p < 0.05$ was considered statistically significant.

## Results

Table I shows the demographic characteristics of the study population. Compared with the MF-BIS method, the Watson formula overestimated TBW in normally hydrated patients, but underestimated TBW in severely overhydrated patients. Compared with the healthy controls, the PD patients had significantly lower ICW volumes.

Bland–Altman analysis of the differences in TBW determined by the two methods found that $TBW_{\text{Watson}}$ overestimated $TBW_{\text{MF-BIS}}$ in normally hydrated patients [Figure 1(A)], but underestimated $TBW_{\text{MF-BIS}}$ in severely overhydrated patients [Figure 1(B)]. However, in mildly overhydrated patients, the results of the two methods were not significantly different.

To explore the effect of nutrition status on the difference in TBW determined by the two methods, we analyzed only the patients in the normally hydrated group, re-grouping them according to their SGA classification (Table II). Compared with well-nourished euvoletic patients, malnourished euvoletic patients had significantly less ICW. In well-nourished PD patients, the $TBW_{\text{Watson}}$ somewhat overestimated $TBW_{\text{MF-BIS}}$ [Figure 1(C)], but the difference was even greater in malnourished euvoletic patients [Figure 1(D)].

## Discussion and conclusions

Targets for small-solute clearance are traditionally adjusted for body size by normalizing values according to total body water. The Watson equation is universally recommended by clinical guideline committees

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal hydration (&lt;2.0 L)</th>
<th>Overhydration</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mild (2.0–4.0 L)</td>
<td>Severe (&gt;4.0 L)</td>
</tr>
<tr>
<td>Participants (n)</td>
<td>101</td>
<td>61</td>
<td>33</td>
</tr>
<tr>
<td>Age (years)</td>
<td>58.9±16.5</td>
<td>63.1±12.8</td>
<td>63.5±10.3</td>
</tr>
<tr>
<td>Sex (% men)</td>
<td>31.7</td>
<td>55.7</td>
<td>66.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>59.0±11.7</td>
<td>63.1±10.2</td>
<td>64.4±12.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>157.8±8</td>
<td>161.5±8</td>
<td>163.2±9</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.7±4.2</td>
<td>24.2±3.6</td>
<td>24.1±3.8</td>
</tr>
<tr>
<td>Watson formula</td>
<td>31.1±5.6</td>
<td>33.5±5.2</td>
<td>34.6±5.5</td>
</tr>
<tr>
<td>MF-BIS</td>
<td>29.4±6.5</td>
<td>32.9±6.0</td>
<td>35.4±6.5</td>
</tr>
<tr>
<td>ICW (L)</td>
<td>15.6±4.1</td>
<td>16.4±3.7</td>
<td>16.6±3.7</td>
</tr>
<tr>
<td>ECW (L)</td>
<td>13.8±2.6</td>
<td>16.5±2.4</td>
<td>18.8±3.1</td>
</tr>
<tr>
<td>ECW/ICW (%)</td>
<td>90.7±13.2</td>
<td>101±12</td>
<td>116±16</td>
</tr>
</tbody>
</table>

BMI = body mass index; MF-BIS = multi-frequency bioelectrical impedance spectroscopy; ICW = intracellular water; ECW = extracellular water.
to estimate total-body volume for the calculation of PD adequacy. Our study demonstrated that hydration status and nutrition status both significantly affect $TBW_{\text{Watson}}$ (compared with the $TBW_{\text{MF-BIS}}$), thus leading to a difference in the actual delivered $Kt/V$ urea compared with the $Kt/V$ urea assessed using $TBW_{\text{Watson}}$.

Some earlier studies have focused on the effect of variation in body composition—in particular, the variation of fat and lean tissue mass—on the $TBW_{\text{Watson}}$ (1). In those studies, the Watson formula tended to overestimate TBW in obese patients and to underestimate TBW in lean subjects (5–7). Those findings can be partly explained by the fact that adipose tissue contains less water, about 10%–30% (1); lean tissue contains about 70% water. Isotopic dilution determinations (for example, using deuterium or $^{18}$O-labeled water) are considered the “gold standard” for measuring volume status (11). However, the dilution approach is not practical for routine clinical practice because it requires an equilibration time of at least 3 hours and a subtle laboratory analysis. However, MF-BIS has been validated against isotopic dilution methods in healthy subjects and in dialysis patients (9,12,13). By assessing the resistance of the body to an alternating current, MF-BIS can also be used to estimate ECW and ICW (14). Interest in MF-BIS has been increasing in the dialysis community because of the technique’s simplicity and

![Figure 1](image_url)
reproducibility. Our previous studies validated the use of MF-BIS in PD patients and found that 2 L of OH can be used as the cut-off value for normal hydration status in our stable PD outpatients (15).

Like the Watson formula, most anthropomorphic equations have been derived using predominantly Northern European populations, and recent studies have shown that the Watson formula overestimates TBW in some ethnic groups. Compared with the use of MF-BIS, the Watson formula was shown to potentially overestimate TBW in racial groups prone to type 2 diabetes (4). However, it should be recognized that ethnicity can also have a significant impact on both the hydration and the nutrition status of PD patients. The present study clearly demonstrates the effect of hydration status determined by MF-BIS on TBW

Interestingly, we found that, although the Watson formula overestimated TBW in normally hydrated patients (which would lead to a reduction in the dialysis adequacy calculated based on urea clearance), it underestimated TBW in severely overhydrated patients (which would overestimate the dialysis adequacy calculated based on urea clearance, potentially leading to a reduction in the dialysis dose prescribed to volume overloaded patients, further compounding protein–energy wasting). Clearly, these possible limitations with respect to the accuracy and precision of the Watson formula when used in PD patients can lead to inaccurate Kt/V estimations and might in part explain why past studies in PD patients have been unable to reproduce the close relationships between Kt/V urea and clinical outcomes demonstrated in hemodialysis patients (16).

**Disclosures**

The authors have no financial conflicts of interest to declare.

**References**


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