Influence of body position, food and beverage consumption on BIS measurements

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Abstract. Continuous monitoring of fluid changes using bioimpedance spectroscopy (BIS) during hemodialysis could help to predict hypotensive complications and extend the patient’s life. Food and beverage consumption during the treatment may influence the measurements and the calculated fluid removal. In the present article the change observed in whole body and segmental (knee-to-knee, abdomen) BIS measurements following a sequence similar to the one of dialysis treatment (lying down, sitting and eating, lying down) on healthy subjects is presented. The measurements have been performed using a commercial bioimpedance device with a frequency range of 5 kHz to 1 MHz. Knee-to-knee measurements seem to be less sensitive to these influences, compared to the standard whole body and the alternative abdomen BIS measurements. The results indicate that the individual influence of both body posture and food and beverage consumption may be superposed when combined.

1. Introduction
Bioimpedance spectroscopy (BIS) measurements enable the determination of body fluid content, constituting a method easier to use and to implement compared to the standard methods [1], [2]. Its implementation in a continuous monitoring application could be combined in future with intelligent textiles [1] for the hemodialysis treatment, where continuous monitoring of body fluids could help to predict hypotensive complications and to extend the life of the patient [3]. Despite these advantages, BIS measurements are mostly limited to laboratory conditions, including a determined body posture, no consumption of food or beverage, etc. These conditions cannot be fulfilled during the dialysis therapy, where the patients remain 3 - 5 hours on a dialysis chair or a bed and change their body posture (sitting or lying down) and sometimes have a small meal and a drink.

The influence of body position on BIS measurements is produced by body fluids redistribution [4], [5], [6]. A change from vertical (or sitting) to horizontal position produces a fluid shift from the extremities into the torso [7], which produces an increase of the extremities’ impedance and a decrease of torso impedance [4]. As the torso contributes approx. to only 5% of the whole body impedance, the measured whole body impedance will increase [4], [5]. A change from horizontal to vertical (or sitting) position produces the opposite situation: a fluid shift from the torso into the extremities and a
reduction of the whole body impedance [4], [5]. Keeping a specific body position shows no stabilization, even after 4 hours’ time [6].

Food and beverage consumption produces an increase of whole body impedance (one hour after consumption) and a decrease two hours later [8]. The continuous increase of body impedance due to ultrafiltration during dialysis seems to be interrupted during food consumption [9].

The purpose of the present article is to compare the magnitude of both influences and of the combined result on whole and segmental BIS measurements on healthy subjects.

2. Basics of bioimpedance spectroscopy (BIS)

Total body fluid (TBF) in humans consists of intracellular (ICF) and extracellular fluids (ECF), separated by the cellular membrane. The ECF, which includes the interstitial fluid and plasma, and the ICF are predominantly electrical resistive entities, whereas the cellular membrane has a capacitive character. Accordingly a low frequency current only flows around the cells through the ECF, whereas a high frequency current will also pass through the cell membrane and the ICF (see figure 1 left).

![Figure 1](image1.png)

Figure 1. Low and high frequency current flow through body tissue.

This phenomenon can be represented by the electrical model given in figure 1 (right) [10]. Taking into consideration a heuristic factor \( \alpha \) representing different tissues in parallel with specific time constants and a time delay \( T_D \) produced by the speed of signal transmission through measurement cables, the measured impedance can be written as follows:

\[
Z(j\omega) = \frac{R_e}{R_e + R_i} + \frac{R_e}{1 + (j\omega C_m (R_e + R_i))^2} e^{-j\omega T_D}
\] (1)

The values of the electrical model \( R_e, R_i \) and \( C_m \) can be determined by fitting the modified Cole model [11] of (1) to the impedance measured at different frequencies (\( \omega \)). Using the Cole parameters \( R_e, R_i \) and \( C_m \), the basics of Hanai Theory [12] and devising the human body as a cylindrical volume, the body fluids volumes (ECF, ICF, TBF) can be calculated [13].

3. Materials and methods

3.1. Whole body and segmental BIS measurements

Whole body and segmental BIS measurements (Xitron Hydra 4200, Xitron Technologies Inc. San Diego, CA, USA) were performed on 4 healthy test subjects, 1 female and 3 males aged between 23 and 27 (see figure 2). Abdomen measurements were performed only on 2 male subjects. Since the expected body fluid changes and redistribution (due to ultrafiltration or changes in body posture respectively) are mainly limited to the extracellular compartment [2], [13], only \( R_e \) has been taken into account for the present study.
3.2. Influence of body posture and food and beverage consumption during hemodialysis situation

In order to evaluate the influence of changes in body posture and of food and beverage consumption (as during dialysis) on BIS measured values two sequences were used.

Sequence A: 15 min sitting, 60 min lying down, 60 min sitting and 30 min lying down. No food or beverage consumption was allowed. The bed setup for the lying down and sitting position was registered for every subject at the beginning and was used for the whole experiment.

Sequence B: same as Sequence A, with consumption of food (a pizza of approx. 30 cm of diameter) and beverage (a 200 ml soda drink) being allowed during the second sitting phase (60 min).

The measurements were performed in the dialysis clinic of the university hospital (RWTH Aachen university), room temperature 24 °C, using hospital beds for dialysis treatment. A period of at least 4 hours without eating or drinking and 48 hours without doing sports were prerequisite for the tests.

Assuming a superposition of both influences (body posture and food and beverage consumption) in sequence B, the influence from food and beverage consumption alone is found from the difference between both sequences as follows:

\[
R_{e, \text{Food Consumption}} = R_{e, \text{Sequence B}} - R_{e, \text{Sequence A}}
\]  

(2)

4. Results

The relative change of \( R_e \) (mean values) for all the measurements is given in figure 3. The maximum relative change in \( R_e \) (mean values) for each sequence have been summarized in table 1.

![Figure 3](image-url)

**Figure 3.** Relative \( R_e \) (mean) values for sequences A and B and their difference (as calculated with (2)) on whole body (a), knee-to-knee (b) and abdomen (c) measurements.

**Table 1.** Maximum relative change (start value as reference) in \( R_e \) (in %) during both sequences and their difference.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Sequence A</th>
<th>Sequence B</th>
<th>Difference (B-A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body</td>
<td>+ 4.5</td>
<td>+ 6.0</td>
<td>+ 1.8</td>
</tr>
<tr>
<td>Knee-to-knee</td>
<td>+ 2.0</td>
<td>+ 1.6</td>
<td>- 1.6</td>
</tr>
<tr>
<td>Abdomen</td>
<td>- 5.0</td>
<td>- 8.5</td>
<td>- 3.0</td>
</tr>
</tbody>
</table>

Sequence A (influence of body posture): \( R_e \) values change as expected [5] for whole body BIS measurements; increases during the first lying position, decreases during the sitting position and rises up again during the final lying position. A similar pattern of change is observed with knee-to-knee and abdomen measurements (see figure 3). Magnitudes of change in whole body and abdomen measurements are bigger than on knee-to-knee measurements (see table 1).

Sequence B (Influence of body posture combined with food and fluid consumption): the combined influence on \( R_e \) relative change can be seen during the sitting and second lying down position. Compared to the values of sequence A, the direction of the change in every body posture remained the same, but the magnitude of the change has been either reduced or increased. For whole body
measurements, the form of the change resembles the one associated to food consumption during a dialysis treatment [9]. Changes in knee-to-knee measurements showed again the smallest change.

The influence of food and beverage consumption alone is calculated according to (2). $R_e$ increases with food consumption in whole body measurements as reported by Fogelholm et al. [8]. The calculated magnitude of change one hour after meal intake (1%) is slightly higher than the reported one (0.6%) [8]. It is not possible to confirm the subsequent reported decrease due to the short time. The other results could not be compared with other investigations, as similar experiments were not found in the literature. The biggest change was observed on the abdomen, where $R_e$ values decrease, most probably due to an increase of local blood perfusion related with digestion. The use of (2) for whole body measurements seems to be validated by the agreement of the calculated change with values of the literature and by the small difference of both sequences in the first period (influence of body posture alone). In the case of abdomen measurements, the validity of the superposition principle seems to be limited: see differences between sequence A and B in the first period (influence of body posture alone). Further validation may consider a higher number of test subjects.

5. Conclusions

The present preliminary study indicates that body posture and food consumption influence BIS measurements in different magnitude, depending on the place measured and probably superposing each other. Knee-to-knee measurements seem to be much less influenced (up to 2 %) in contrast to abdomen and whole body measurements (up to 9 %). Whole body measurements during dialysis may be more influenced by the change of body posture related to the consumption of food than from the consumption of food itself.

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References