Application of Longitudinal and Transversal Bioimpedance Measurements in Peritoneal Dialysis at 50 kHz

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Abstract. More relevant information of the fluid changes in peritoneal dialysis (PD) might be obtained with segmental bioimpedance measurements rather than whole-body measurement, who hidden information of body composition. Whole-body and segmental bioimpedance measurements were obtained using 5 configurations (whole-body or right-side (RS), longitudinal-leg (L-LEG), longitudinal-abdomen (L-AB), transversal-abdomen (T-AB), and transversal-leg (T-LEG)) in 20 patients: 15 males (56.5 ± 9.4 yr, 24.2 ± 4.2 kg/m2) and 5 females (58.4 ± 7.1 yr, 28.2 ± 5.9 kg/m2) in peritoneal dialysis (PD). The aim of this study is to analyze the relationship between whole-body, longitudinal-segmental (L-LEG and L-AB) and transversal-segmental (TAB and TLEG) bioimpedance measurement at 50 kHz, with clinical parameters of cardiovascular risk, dyslipidemia, nutrition and hydration. The Kolmogorov-Smirnov test was used for the normality test of all variables. Longitudinal bioimpedance parameters were normalized by the height of the patients. The Spearman correlation was used to analyze the correlation between bioimpedance and clinical parameters. The statistical significance was considered with P < 0.05. Transversal bioimpedance measurements have higher correlation with clinical parameters than longitudinal measurements.

1. Introduction

Body composition analysis is based nowadays mainly based on body weight and an examination of soft tissues. One of the alternative techniques for body composition assessment in clinical practice is bioelectrical impedance, as a simple, non-invasive, innocuous and repeatable method [1]. Moreover, bioelectrical impedance vector analysis [2] does not require any assumption about constant soft tissue hydration and body composition and is independent of the body weight.

The patient in peritoneal dialysis session represents an ideal model for studying localized changes in body fluid. Each body segment such as: leg, arm, thorax, abdomen, has its own characteristic pattern of fluid shift in response to PD fluid exchange [3, 4]. The value of the whole-body impedance is the addition of the right arm, the thorax, the abdomen and the right leg impedances. In PD patients, the approximate percentage contributions to whole-body resistance (longitudinal measurement) were: thorax 1%, abdomen 5%, leg 43% and arm 51% [5, 6].

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The aim of this study is to analyze the relationship between whole-body, longitudinal-segmental (L-LEG and L-AB) and transversal-segmental (T-AB and T-LEG) bioimpedance measurement at 50 kHz, with clinical parameters of cardiovascular risk, dyslipidemia, nutrition and hydration.

2. Methods

2.1 Patients

Twenty patients in continuous ambulatory peritoneal dialysis (CAPD): 15 males (56.5 ± 9.4 yr, 24.2 ± 4.2 kg/m2) and 5 females (58.4 ± 7.1 yr, 28.2 ± 5.9 kg/m2) at the Service of Nephrology of the Fundació Puigvert (Barcelona, Spain) were analyzed by bioimpedance. Clinical evaluation, laboratory determinations, and bioimpedance measurement were carried out in the morning, before the second daily fluid drainage of the abdominal cavity.

The following clinical parameters were measured: systolic and diastolic blood pressure (SBP and DBP), mean blood pressure (BPmean), haematocrit, cholesterol, triglycerides, low-density lipoprotein (LDL, col), high-density lipoprotein (HDL, col), total protein (Tprot), albumin and C-reactive protein (CRP).

2.2 Bioimpedance Measurements

Impedance measurements were taken with model STA-BIA (Akern, Florence-Italy) at 50 kHz with injected current of 800 μA. The specific measurement error of the system is lower than 1 Ω and 1° at 50 kHz using electrical models. Disposable pre-gelled Ag/AgCl (3M Red Dot, Canada) electrodes were used.

The tetrapolar measurements (two electrodes for injecting current (I) and two for sensing voltage (V)) were located on the patients in supine decubitus. Electrode positions are shown in figure 1. Longitudinal current injection electrodes were located in 1 and 4 for RS, L-AB and L-LEG, and transversal current injection electrodes were located in 11 and 14 for T-AB and 7-10 for T-LEG. Electrodes for sensing the voltage are:

1. RS: whole-body; the standard whole-body impedance measurement (2-3).
2. L-AB: longitudinal-abdomen; the voltage was measured by using the electrode on the left-foot articulation and on the xiphoid (5-6).
3. L-LEG: longitudinal-leg; this represents the addition of both previous segments from the inguinal region to the malleolar articulation (6-3).
4. T-AB: transversal-abdomen; at the level of the umbilicus (12-13).
5. T-LEG: transversal-right-leg; located in the thigh femoral region (8-9).

Figure 1. Electrode locations for longitudinal and transversal measurements.
2.3 Statistical Methods
The Kolmogorov-Smirnov test was used for the normality test of all variables. All data are expressed as mean values (± SD). The Spearman correlation was used to analyze the correlation between bioimpedance and clinical parameters. In longitudinal bioimpedance segments, the impedance parameters were normalized by the height (H) of the patients. Minitab software version 15.1.0 (Minitab, Inc.) was used for statistical analysis. Statistical significance was considered with p < 0.05. Female sample were not analyze statistically due to the small sample size.

3. Results
Table 1 shows the mean ± standard deviation (SD) for clinical laboratory variables in male and female samples.

Table 1. Clinical laboratory results.

|                  | Males mean ± SD | Females mean ± SD |
|------------------|-----------------|-------------------|
| BMI (kg/m²)      | 24.2 ± 4.2      | 28.2 ± 5.9        |
| SBP (mmHg)       | 133.0 ± 15.6    | 135.0 ± 14.1      |
| DBP (mmHg)       | 78.7 ± 10.4     | 80.1 ± 7.1        |
| BPmean (mmHg)    | 96.8 ± 11.2     | 98.3 ± 7.1        |
| Hematocrit (g/L) | 37.3 ± 4.4      | 35.2 ± 5.3        |
| Cholesterol (mmol/L) | 4.2 ± 0.8   | 4.8 ± 1.5         |
| Triglycerides (mmol/L) | 1.4 ± 0.6    | 2.1 ± 1.9         |
| LDL, col (mmol/L)| 2.5 ± 0.7       | 2.2 ± 1.2         |
| HDL, col (mmol/L)| 1.1 ± 0.3       | 1.2 ± 0.4         |
| T.Protein (g/L)  | 62.4 ± 6.3      | 63.0 ± 3.1        |
| Albumin (g/L)    | 35.8 ± 5.3      | 37.5 ± 3.2        |
| CRP (mg/L)       | 2.7 ± 1.7       | 3.7 ± 3.9         |

Table 2 shows the mean ± standard deviation (SD) of impedance parameter; resistance (R) and reactance (Xc) divided by height of the patients in the longitudinal measurements (RS, L-LEG and L-AB) and in transversal impedance segment (T-LEG, T-AB).

Table 2. Mean ± SD of impedance for each segment.

|                  | Males N=15 | Females N=5 |
|------------------|------------|-------------|
| R/H Xc/H         |            |             |
| RS               | 308.9 ± 91.1 | 331.4 ± 57.7 |
| L-LAB            | 24.8 ± 5.8  | 24.2 ± 3.3   |
| L-LEG            | 218.5 ± 74.5| 221.8 ± 31.3 |
| T-AB             | 30.5 ± 10.4 | 41.6 ± 17.0  |
| T-LEG            | 26.8 ± 7.4  | 30.4 ± 6.2   |

Table 3 shows the Spearman correlation results between the bioimpedance and clinical parameters in the male sample. Only segments and clinical variables with significant correlations are shown.
Table 3. The Spearman correlation between impedance and clinical parameters for the male sample.

| Parameter        | Rho  | P     | Rho  | P     | Rho  | P     | Rho  | P     | Rho  | P     | Rho  |
|------------------|------|-------|------|-------|------|-------|------|-------|------|-------|------|
| SBP (mmHg)       | -0.643 | 0.015 | -0.575 | 0.033 | -0.617 | 0.019 | 0.570 | 0.033 | 0.642 | 0.013 | 0.617 |
| DBP (mmHg)       | - - | - - | 0.610 | - - | 0.021 | - - | 0.660 | - - | 0.010 |
| BPmean (mmHg)    | - - | - - | 0.610 | - - | 0.021 | - - | 0.660 | - - | 0.010 |
| T.Protein (g/L)  | 0.570 | 0.033 | 0.013 | 0.013 |
| Albumin (g/L)    | 0.642 | 0.013 | 0.013 |
| CRP (mg/L)       | - - | - - | 0.642 | 0.013 |
| Triglyc. (mmol/L) | - - | - - | 0.642 | 0.013 |
| LDL, col (mmol/L) | - - | - - | 0.642 | 0.013 |

4. Discussion and Conclusions
The real part of the complex impedance (resistance, R) provides information of the hydration state, and imaginary part (reactance, Xc) the structure of soft tissue [2]. The resistance (R), in transversal impedance measurements in right leg (T-LEG), shows high correlation with parameters of cardiovascular risk such as systolic and diastolic blood pressure, and as consequence with mean blood pressure; also with hydration and nutrition state such as, total protein, albumin and C-reactive protein. The resistance parameters, in transversal impedance measurements in the abdomen segment (T-AB), show high correlation with nutrition and dyslipidemia parameters such as total protein and triglycerides respectively. The imaginary part of the complex impedance, reactance (Xc) normalized by the height of the patients, in longitudinal impedance measurement in right leg (L-LEG), show high correlation with parameter of dyslipidemia, such as low-density lipoprotein (LDL, col). These results are in agreement with the complex changes and alterations in body composition due to renal insufficiency. The patients with terminal chronic renal failure present dysfunctions in the distribution of the body water (fluid-overloaded), malnourishment and muscle wasting. Sub-clinical volume overload is a frequent complication of peritoneal dialysis patients associated with hypertension and increased cardiovascular risk. A careful choice of electrode placement will enable the user to focus the measurements on the desired structure of the human body.

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