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Oszacowanie przestrzeni zewnątrzkomórkowej przy pomocy techniki bioimpedancji elektrycznej całego ciała i segmentalnej u pacjentów hemodializowanych

Streszczenie

Wstęp. Monitorowanie stanu nawodnienia pacjentów dializowanych stanowi istotny aspekt kliniczny jakości ich leczenia. Bioimpedancja elektryczna jest jednym z narzędzi, które służy określaniu stanu nawodnienia.

Cel. Celem pracy było zbadanie różnicy w wielkości przestrzeni zewnątrzkomórkowej w grupie pacjentów hemodializowanych.

Materiał i metody. Badania prowadzono za pomocą dwóch metod: metody bioimpedancji całego ciała i segmentalnej – WBIA i SBIA. Do pomiarów bioimpedancji użyto analizatora bioimpedancji (model 4000B, Xitron Technologies, San Diego, CA, USA) przy użyciu elektrod (7,7 x 1,9 cm²). Bioimpedancję mierzono w logarytmicznym spektrum 10 częstotliwości, rozpoczynając od 5 do 500 kHz. Pomiary zostały przeprowadzone u 10 pacjentów przewlekle hemodializowanych, w tym 5 kobiet i 5 mężczyzn w wieku od 33 do 69 lat (średnia 41,5 roku) przed i po hemodializie.

Wyniki. W badaniu różnic pomiędzy wielkościami ECW mierzonymi przy pomocy dwóch metod – metody bioimpedancji całego ciała i segmentalnej stwierdzono istotną statystycznie różnicę zarówno przed jak i po dializie (odpowiednio $t = -7{,}49$; $p = 0{,}0004$ i $t = -9{,}81$; $p < 0{,}000004$). Natomiast w badaniu różnic pomiędzy wartościami oporu elektrycznego R_e przed i po dializie mierzonymi przy pomocy dwóch metod nie stwierdzono istotnej statystycznie różnicy ($p > 0{,}05$).

Wniosek. Uzyskane rezultaty pozwalają wysunąć wniosek, iż bioimpedancja segmentalna, określając stan nawodnienia poszczególnych części ciała ludzkiego, może stanowić dokładniejsze narzędzie służące monitorowaniu stanu nawodnienia pacjentów dializowanych.

Słowa kluczowe: metoda bioimpedancji całego ciała, metoda bioimpedancji segmentalnej, hemodializa, przewlekła niewydolność nerek, przestrzenie pozakomórkowe.

Extracellular water compartment measured with the use of whole body and segmental bioimpedance technique in hemodialyzed patients

Abstract

Introduction. Monitoring of hydration levels in dialyzed patients is an important clinical aspect of the quality of treatment. Bioelectric impedance has been established as a valuable tool in the evaluation of hydration state.

Aim. The aim of this study was to assess the differences in the sizes of the extracellular compartments measured with the use of two methods.

Material and methods. The study was conducted with two methods: the whole body bioimpedance and segmental bioimpedance – WBIA and SBIA. Bioimpedance measurements were performed with a bioimpedance analyzer (model 4000B, Xitron Technologies, San Diego, CA, USA) with electrodes (7.7 x 1.9 cm²). Bioimpedance was measured in a logarithmic spectrum of 10 frequencies starting from 5 to 500 kHz. The readings were carried out for 10 chronically haemodialyzed patients, 5 females and 5 males aged between 33 and 69 years (average 41.5 years old)

Results. In the study on differences between ECW values measured with the use of two methods – the whole body bioimpedance and segmental bioimpedance, statistically significant difference was detected both before and after the dialysis ($t = -7.49$; $p = 0.0004$ and $t = 9.81$; $p < 0.000004$, respectively). However, no statistically significant difference was found when values of electrical resistance Re were measured before and after the dialysis with the use of the two methods ($p > 0.05$).

Conclusion. The obtained results demonstrate that segmental body bioimpedance determining the hydration level in various parts of the body is a more precise tool in monitoring the hydrate status in hemodialyzed patients.

Key words: whole body bioimpedance technique, segmental bioimpedance technique, hemodialysis, chronic renal failure, extracellular compartment.

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INTRODUCTION

Evaluation of hydration levels in dialyzed patients is an essential part of dialysis therapy specifically because of the risk of over-hydration and its association with arterial hypertension, and/or dehydration that leads to hypotonia during dialysis [1-4]. Elimination of fluid excess during dialysis treatment is achieved with the use of ultrafiltration so that the patient reaches a weight called "optimal dry weight." Optimal dry weight is often defined as "target weight". Optimal dry weight is described as the lowest body mass which is tolerated by a patient without an occurrence of side effects during dialysis or hypotonia at the end of the dialysis session [5]. Complications during dialysis can be caused by an imbalance between the ultrafiltration rate and the plasma refilling index [6]. The removal of fluid through ultrafiltration occurs first from intravascular space and central segment of the body (trunk) [7]. At the same time, fluids flow from peripheral segments (interstitial) into the central compartment (trunk). This movement of fluid between compartments, moving from interstitial to intravascular space (refilling), causes a change in the total blood volume in that compartment. The rate at which refilling occurs is known as the plasma refilling index in the intravascular compartment [8]. During dialysis treatment, when the ultrafiltration rate is higher than the plasma refilling index, a patient has a greater risk that hypotonia will occur [9].

Unfortunately, there is no current standardized method of evaluating dry weight in dialyzed patients. Therefore, it is very difficult to set an ideal ultrafiltration rate and level for each patient to decrease the risk of complications occurring during dialysis [10]. In many dialysis centers optimal dry weight is assessed by clinical examination [11]. This method, while incorporating many components specific to this population, unfortunately, continues to underestimate over-hydration or dehydration in these patients. Many other techniques have been used to compensate or assist in the evaluation of hydration status in this population.

Monitoring of hydration levels in dialyzed patients is an important clinical aspect of the quality of treatment, as previously stated. When a current method for monitoring hydration is inadequate, another method must be considered to provide increased or improved quality of treatment for this patient population. As stated earlier, fluid removed from the patient during dialysis is removed with the use of ultrafiltration mainly from the intravascular space. Knowledge and understanding of other fluid compartments of the body during this dynamic process can be beneficial in reducing complications associated with this therapy. Bioimpedance has been established as a valuable tool in the evaluation of hydration states of various compartment of the body in the dialyzed patient [12,13].

The bioimpedance technique incorporates a precise evaluation of hydration levels utilizing physiological data concerning assessment of water compartments sizes, such as TBW (total body water), ECW (extracellular water), ICW (intracellular water) and interstitial compartment [14]. The specific mechanisms of this technique are based on an elementary principle that electrical resistance of a cylinder is directly proportional to the length and inversely proportional to the cross section area of the cylinder multiplied by the density. This method is based on the evaluation of electrical resistance in body tissues with relationship to an alternating multi frequency, amplitude current [15].

Although, the principal bioimpedance techniques were first introduced by Thomassett in 1963, increased interest in this technique appeared in the early seventies of the last century when Nyboer demonstrated a correlation between bioimpedance value assessed with the use of an alternating current and changes in the blood volume [16]. Many articles described the method of the whole body bioimpedance analysis (WBIA). WBIA's method places electrodes on the palm and the foot (the wrist and ankle placement of electrodes have also been used). An alternating current, with frequencies from 5 to 500 kHz reaches the electrodes placed at the level of metacarpophalangeal joint in finger III of the upper extremity and at the base of metatarsophalangeal joint in toe II and III of the lower extremity – the voltage is measured between electrodes placed on the wrist in an imagined line connecting the styloid process of the ulnar bone with the styloid process of the radial bone and an electrode placed in a line connecting the medial and lateral condyle. It is possible, using the bioimpedance technique to choose an option of one current frequency usage or a multi-frequency option with an amplitude from a few to a few hundred (500) kHz. It should be noted that WBIA assessment is dependent on changes in the body position. Therefore, body position changes must be considered when analyzing results using this method. Segmental bioimpedance technique (SBIA) is an assessment of independent body segments, such as upper extremities, trunk, and lower extremities. The analysis of the results using this technique has been observed to be a more precise evaluation of hydration states and dynamical changes during dialysis session.

A bioimpedance technique provides a useful method to assess the size of TBW and ECW compartments during the dialysis process. The purpose of this study was to evaluate the accuracy of the two methods by which the hydrate status can be measured- the whole body and segmental bioimpedance technique.

AIM

The aim of this study was to assess the differences in the sizes of the extracellular compartments measured with the use of two methods

MATERIAL AND METHODS

The study was conducted with two methods: the whole body bioimpedance and segmental bioimpedance – WBIA and SBIA (readings were carried out for 10 chronically haemodialyzed patients, 5 females and 5 males aged between 33 and 69 years (average 41.5 years old).

Clinical and biochemical characteristics in the study group patients are presented in Table 1.

Anthropometric characteristics in the study group patients are presented in Table 2.

TABLE 1. Clinical and biochemical characteristics in the study group patients.

Parameter	Mean (M)	SD
Age (years)	41.5	11.55
Dialysis time (months)	25.2	32.17
BMI (kg/m²)	24.2	2.70
Kt/V	1.28	0.22
Albumin level (mg/dl)	3.85	0.18
Systolic BP before HD (mmHg)	157	20.29
Diastolic BP before HD (mmHg)	97	11.91
MAP before HD (mmHg)	115.61	14.73
Systolic BP after HD (mmHg)	148.7	26.31
Diastolic BP after HD (mmHg)	96	17.30
MAP after HD (mmHg)	115	18.73
Weight before HD (kg)	69.73	7.70
Weight after HD (kg)	67.28	7.88
Dry weight (kg)	67.5	7.70

TABLE 2. Anthropometric characteristics in the study group patients.

Parameter	Mean (M)	SD
Length of arm (cm)	55.21	3.14
Maximal circumference of arm (cm)	40.99	2.62
Minimal circumference of arm (cm)	17.47	1.11
Length of chest (cm)	40.6	5.05
Maximal circumference of chest (cm)	105.19	7.62
Minimal circumference of chest (cm)	89.52	17.38
Lenght of chest (cm)	85.27	3.02
Maximal circumference of leg (cm)	63.78	9.37
Minimal circumference of leg(cm)	23.49	1.06

For the state of hydration in the study group patients see Table 3.

Inclusion criteria:

- Patients diagnosed with chronic renal failure (CRF) were included in the study
- Ages between 18 and 80 years
- Clinically stable
- Written consent of the patients for participation in this study

Exclusion criteria:

- Patient with mental problems
- Pregnancy or lactation patients
- Patients with amputation of a lower limb
- Patients with an implanted pacemaker
- Patient with severe hemodynamic circulatory insufficiency

Measurements:

The following parameters were measured in each patient:

- Body mass before and after hemodialysis (in kg)
- Height of patient (in cm)
- Blood pressure before hemodialysis

Anthropometric measurements

- Body mass of a patient was measured with the use of a scale with an acceptable deviation of 0.1 kg
- Height of a patient (in cm without shoes) was measured with the use of a standard measure.

Electrical bioimpedance measurements

Bioimpedance measurements were performed with a bioimpedance analyzer (Bioimpedance spectroscopy device 4000B, Xitron Technologies, San Diego, CA, USA measuring at 50 frequencies between 5 kHz and 1 MHz) with electrodes (7.7 x 1.9 cm²). The software for this device is the fluid management tool (FMT ver. 2.0).

TABLE 3. State of hydration in the study group patients.

Parameter	Mean (M)	SD
ECW WBIA before HD (l)	17.30	2.07
ECW WBIA after HD (l)	14.84	1.31
Δ ECW WBIA (l)	2.46	0.89
ECW of arm before HD (SBIA) (l)	1.13	0.22
ECW of arm after HD (SBIA) (l)	1.01	0.17
Δ ECW of arm (SBIA) (l)	0.12	0.07
ECW of chest before HD (SBIA) (l)	4.37	0.80
ECW of chest after HD (SBIA) (l)	3.78	0.69
Δ ECW of chest (SBIA) (l)	0.60	0.40
ECW of leg before HD (SBIA) (l)	3.32	0.50
ECW of leg after HD (SBIA) (l)	2.81	0.43
Δ ECW of leg (SBIA) (l)	0.51	0.15
Sum of segments before HD (l)	13.26	1.86
Sum of segments after HD (l)	11.42	1.28
Δ Sum of segments (l)	1.84	0.67
Re WBIA before HD (Ohm)	558.12	68.11
Re WBIA after HD (Ohm)	674.06	67.24
Δ Re WBIA	115.94	31.39
Re of arm before HD (Ohm) (SBIA)	262.07	25.05
Re of arm after HD (Ohm) (SBIA)	302.06	16.37
Δ Re of arm (SBIA)	39.99	17.59
Re of chest before HD (Ohm) (SBIA)	43.2	7.90
Re of chest after HD (Ohm) (SBIA)	52.52	9.70
Δ Re of chest (SBIA)	9.32	7.57
Re of leg before HD (Ohm) (SBIA)	254.83	46.93
Re of leg after HD (Ohm) (SBIA)	323.13	52.75
Δ Re of leg (SBIA)	68.3	18.63
Sum of Re before HD (SBIA)	560.1	70.35
Sum of Re after HD (SBIA)	677.71	64.69
Δ Sum of Re (SBIA)	117.61	30.25

Study protocol

All parameters were measured at the beginning and at the end of hemodialysis. Parameters were not measured during dialysis treatment to avoided errors in evaluation of the data, as the greatest fluid distribution occurs within the first hour of hemodialysis.

Examination procedure

Patients were placed in a reclining position 10 minutes before WBIA was preformed. Bioimpedance was measured in a logarithmic spectrum of 10 frequencies starting from 5 to 500 kHz. Two electrodes inducing an alternating current were placed dorsally on the hand (I1) and ankle (I2) on the same side of the patient's body.

Measuring electrodes were placed on the wrist (S1), the ankle (S2) and the chest (S3) on the same side of the patient's body. A computer was used to collect and store data, from each measurement.

Statistical methods

Our results were statistically analyzed. Analysis parameters included arithmetical mean (M), standard deviation

(SD) with a defined range of variability (Min – Max) and confidence interval for the mean (95 % Cl). Shapiro-Wilk (S-W) test was used to assess the distribution conformity of the examined parameters with a normal distribution; the Fisher (F) test was used to assess variance homogeneity. To compare the two groups (independent samples) according to the type of distribution and variance homogeneity Student's T-Test or Cochrane-Cox test was used; Student's T-test was used for dependent samples. Non-parametric equivalents of Student's T-test were used for skewed distributions: for independent samples – the Mann-Whitney U test and for dependent samples – a pair sequence Wilcoxon's test. To assess if there was a correlation between two parameters a correlation coefficient significance test (Pearson's r or Spearman's) was used. An accepted conclusion error was 5 % and connected with it statistical significance was $p < 0.05$ which would reveal the existence of statistically significant differences of correlations. The statistical analysis of this study was performed using computer software STATISTICA v.6.0 (StatSoft, Poland).

RESULTS

In the study on differences between ECW values measured with the use of two methods – the whole body bioimpedance and segmental bioimpedance, statistically significant difference was detected both before and after the dialysis ($t = -7.49$; $p = 0.0004$ and $t = 9.81$; $p < 0.000004$, respectively). However, no statistically significant difference was found when values of electrical resistance Re were measured before and after the dialysis with the use of the two methods ($p > 0.05$) (details – Tables 4, 5 and Figures 1, 2, 3 and 4).

TABLE 4. Hydrate status (ECW, ICW, TBW) in the group of hemodialyzed patients.

Parameter	N	Mean (M)	SD	Confidence interwal 95%Cl	Min – Max
ECW SBIA before HD (l)	10	13.26	1.86	11.93-14.59	10.62-15.70
ECW SBIA after HD (l)	10	11.42	1.28	10.51-12.34	9.92-13.11
ECW WBIA before HD (l)	10	17.30	2.07	15.82-18.78	14.46-21.02
ECW WBIA after HD (l)	10	14.84	1.31	13.90-15.78	13.42-17.25
Re SBIA before HD (Ohm)	10	560.10	70.35	509.77-610.43	457.6- 698.600
Re SBIA after HD (Ohm)	10	677.71	64.69	631.43- 723.99	567.10- 761.00
Re BIA before HD (Ohm)	10	558.12	68.11	509.39- 606.85	455.50- 690.20
Re WBIA after HD (Ohm)	10	674.06	67.24	625.96- 722.16	567.30- 762.40

TABLE 5. Table show statistical differences.

	ECW before HD	ECW after HD	R_e before HD	R_e after HD
WBIA	t = -7.49;	t = -9.81;	t = 2.06;	t = 1.22;
SBIA	p = 0.0004	p < 0.000004	p = 0.07	p = 0.25

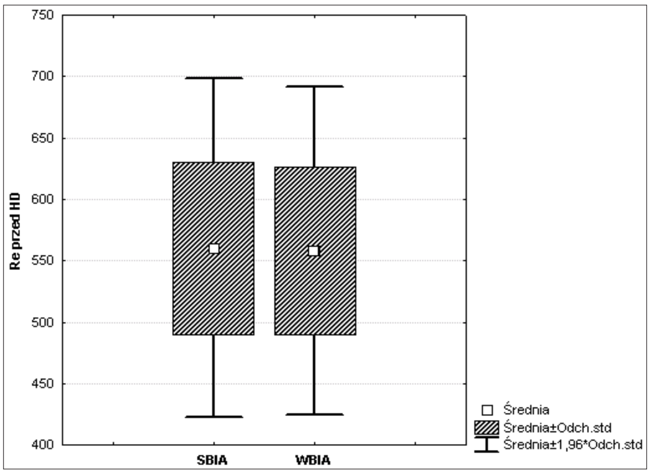

FIGURE 1. Re (in the figure Re) before HD measured with the use of WBIA and SBIA.

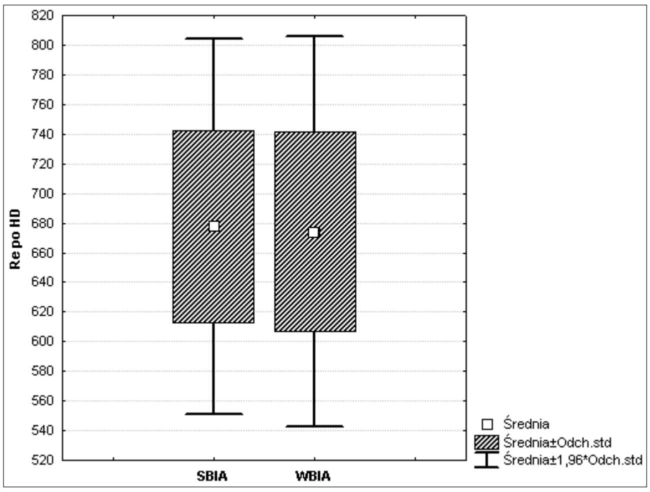

FIGURE 2. Re (in the figure Re) after HD measured with the use of WBIA and SBIA.

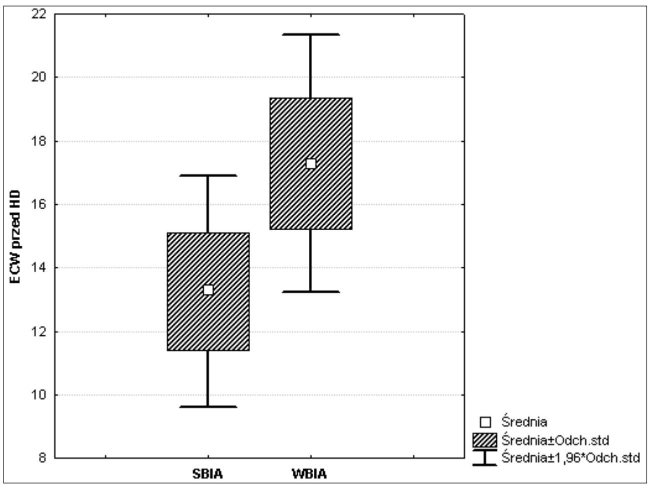

FIGURE 3. ECW before HD measured with the use of WBIA and SBIA.

Średnia - mean value
Odch.std - standard deviation

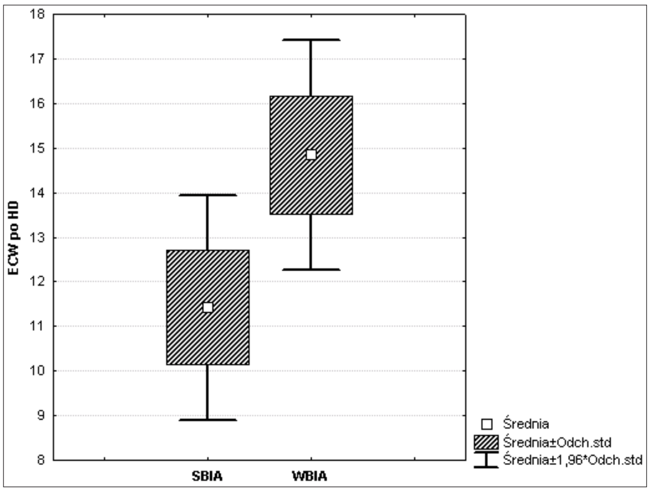

FIGURE 4. ECW after HD measured with the use of WBIA and SBIA.

DISCUSSION

It is clear that a precise evaluation of a human body structure and the state of hydration plays a significant role in obtaining expected dry weight in CRF patients treated with hemodialysis [17]. The assessment of water compartments is vital because it provides an evaluation of optimal hydration state. The total volume of fluid removed during dialysis should be individualized to a patient undergoing this therapy in order to reach an expected dry weight. One of the methods of measuring the state of hydration is the whole body bioimpedance technique. This technique provides as easy to use and non-invasive method of monitoring fluid compartment sizes within the body [18]. In the study, the significant difference in ECW measured by the segmental bioimpedance and the whole body technique was observed. However, the electrical resistance values obtained from the measurements are almost identical. Similar values were obtained by Zhu et al. from the measurements performed on 11 patients [19]. The value of electrical resistance (Re) obtained from the two methods (WBIA and SBIA) was 527 ± 55.6 Ω. The similar value gained by the previously mentioned authors of ECW by WBIA and SBIA were respectively 20.90 and 14.29 litres.

The cause of the difference in the value of ECW measured by WBIA and SBIA is quite complex. One of the hypotheses is the lack of the correlation of the SBIA from the body position changes in comparison to WBIA [19]. The difference in the two methods of measurements can result from the shift of water from the peripheral segments (arms or legs) to the central segment (trunk) at the beginning of hemodialysis. One way to take the measurements from different segments of the body is the digital switch which in a controlled way changes the measurements from one position to another. The manual change of the electrodes, which was used in our study in order to measure a particular segment of the body, can be a cause of the significant discrepancy in the values obtained from the WBIA and SBIA methods.

From the obtained results the conclusion can be drawn that the segmental bioimpedance technique assessing the hydrate status of particular segments of the body can be a useful tool in monitoring the hydrate status of hemodialized patients [20,21].

CONCLUSION

Hydration status is an extremely important factor determining the development of arterial hypertension in hemodialyzed patients. Correct assessment of the body mass (optimal dry weight) is crucial in those patients. The bioimpedance technique provides a useful method to assess the size of TBW and ECW compartments during the dialysis process. There are two ways by which TBW and ECW can be measured – WBIA and SBIA. In our study we observed that the size of extracellular compartments volume (ECW) measured with WBIA was more precise than measured with SBIA.

The results of our study demonstrate that segmental body bioimpedance assessment is a more precise tool in assessing the hydrate status among hemodialyzed patients.

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