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Original Article

Assessment of bioelectrical impedance analysis for determining dry weight in pediatric hemodialysis patients; single center experience

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Abstract
Aim: Maintaining euvolemia is an important purpose in patients on hemodialysis therapy. Multiple-frequency bioimpedance spectroscopy (BIS) appears to be a useful and appropriate technique for assessing hydration status and body composition in hemodialysis patients.The aims of this study were to determine the pre and post hemodialysis hydration status of the pediatric hemodialysis patients by BIS and compare the dry weight determined by BIS to established by clinically.
Material and Methods: Body Composition Monitor (BCM; Fresenius Medical Care, Germany) was performed in 13 pediatric hemodialysis patients in a single center. Patients were measured at the midweek session, once immediately before and once 30 minutes after dialysis. Pre-and post-HD weights, blood pressures, were collected on the day of the BCM measurements.
Results: Seven (53.8%) of the 13 patients were male and 6 (46.2%) were female. The mean age ranged from 11.92 ± 3.13 (5.7-16) years and duration time ranged from 7 to 54 months, and the median duration of dialysis was 11 months. Dry weights which was determined clinically were higher than those calculated by BCM. A significant difference was found between mean values (34,71 ± 12,68 versus 33,71 ± 12,16 kg, Δ: 1 ± 1,51, p = 0.035). There was a high positive correlation between dry weights measured by BCM and dry weight established by nephrologists (r = 0.993, p <0.001).
Conclusion: In assessing dry weight, BCM appears to be a quick and easy-to-use tool that can assist the clinician in hemodialysis treatment and optimizing patient outcomes.

Keywords: Hemodialysis; Dry weight; Bioimpedance spectroscopy; Pediatrics.

INTRODUCTION

Chronic fluid overload is associated with increased risk of hypertension, left ventricular hypertrophy, congestive heart failure and consequent cardiovascular mortality due to hypervolemia in hemodialysis (HD) patients (1,2). To avoid these complications, it is critical to obtain the fluid status at the most appropriate limits. Standard HD therapy is administered 3 times a week for 4 hours, and excess fluid in the patient is removed with ultrafiltration during each session. Therefore, in order to achieve a normal fluid balance, it is very important to accurately measure the hydration state of the patient while prescribing the dry weight which is desired to be reached at the end of HD (3-5).

Traditionally, the dry weight in dialysis patients is determined via clinical assessments such as inter-dialytic weight gain, presence of hypotension or hypertension, and edema. However, interpretation of clinical indicators is subjective and these indicators lack precision (5-8). In this regard, bioelectrical impedance methods have been proposed for the evaluation of body composition and found widespread application in dialysis patients. Owing to their advantages such as ease of application, being a non-invasive convenience, repeated measurements are possible and excellent interobserver reproducibility has been reported (5,6,9-11,13-18). The principle of the use of bioelectrical impedance methods, bioimpedance analysis (BIA) or bioimpedance spectroscopy (BIS)is based on applying alternating currents to the tissue bed at different frequencies through electrodes, and measuring the resistance of the tissue to the electric current (15,19).

BIA measures whole body impedance using one electrical current with a frequency of 50 kHz. This single-frequency BIA provides only one value of impedance which cannot differentiate between extracellular and total body fluid resistances because electrical currents of this frequency do not pass cell membranes. Multi-frequency BIA (mf-BIA) or BIS system relies on a different electrical model. In BIS system that make multi-frequency measuring, the current can distinguish total and extracellular fluid segments in the

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body by passing mainly through extracellular fluid at low frequency, and through the whole body cells at high frequency (13,15,19). With this method, the amounts of intracellular fluid (ICF), extracellular fluid (ECF), and total body fluid (TBF) can be measured. The BIS method has recently been used frequently in hemodialysis patients (5,13,15-19).

The aims of this study were to determine the pre and post hemodialysis hydration status of the pediatric hemodialysis patients by BIS and compare the dry weight determined by BIS to establish by clinically.

MATERIAL AND METHODS

The study population consisted of 13 pediatric patients undergoing HD for more than 6 months. The exclusion criteria were (i) presence of congenital or acquired heart disease, (ii) presence of chronic lung or liver disease, and (iii) evidence of active infection within two weeks prior to the study. Informed consent was obtained from both parents and children for patients aged 11–18 years and from parents only for those 10 years of age and under. This prospective study was conducted in Ondokuz Mayıs University Medical Faculty, Department of Pediatrics, Pediatric Nephrology Unit.

Dry weight was clinically determined by pediatric nephrologists. When calculating the dry weight of the patients, the presence of clinical symptoms such as dyspnea, peripheral edema, and high blood pressure was used. Records of previous sessions were also examined and the ultrafiltration rate was determined for the examined session using this information along with pre-dialysis weight.

BCM (BCM-Fresenius Medical Care D GmbH) - Body Composition Monitor was used to measure fluid status and body composition by the BIS method. Immediately prior to the HD session, the patient was taken to the procedure after being rested in the supine position for at least five minutes. Patients were laid down on a non-conductive surface, and metal fittings were removed before the measurement. Prior to the procedure, skin cleansing was controlled and two adhesive electrodes were placed on the dorsal surfaces of the hand and foot at the same side, perpendicular to the axis of the extremity as described in the instruction manual. During the procedure, attention was paid to avoid touch of the upper extremities to the body and the lower extremities to each other. The persons were connected to the device via these electrodes, and after gender, height (cm), body weight (kilograms), blood pressure (systolic and diastolic mm Hg) data were entered for each patient, the measurements were completed a duration of 1 to 4 minutes. All data were transferred to the Fluid Management Tool for analysis. Post-dialysis BCM measurement was read again 30 minutes after the end of HD. In cases where the quality of the data was not ensured, the measurements were repeated by exchanging the electrode. Fluid load (OH) (L), relative fluid load (OH / ECF) (%), total body fluid (TBF) (L), intercellular fluid (ECF)), the ratio of ECF to ICF (ECF/ICF), lean tissue mass (LTM) (kg), body cell mass (BCM) (kg), and total fat mass (FAT) (kg) parameters were recorded.

Usual dialysis measurements such as blood pressure and weight were carried out before and after HD treatment.

Statistical analysis

Statistical analysis was carried out using "SPSS for Windows © 15.0" (Statistical Program in Social Sciences) computer software was used. Normality of the variables was examined using visual (histogram and probability plots) and analytical (Shapiro-Wilk) tests. The characteristics of the patient group were determined by descriptive statistics. Normally distributed parameters are expressed as mean ± standard deviation (SD), and non-normally distributed parameters as median and distribution (lower - upper limit). Pre- and post-dialysis data were compared "Paired-Samples T test" or "Wilcoxon Signed Ranks test". Correlation coefficients and statistical significances of the intergroup variables were calculated using "Pearson correlation test" or "Spearman test". p values less than 0.05 were considered statistically significant.

RESULTS

Of all patients evaluated 7 (53.8%) were boys and 6 (46.2%) were girls with a mean age of 11.92±3.13 (5.7 - 16) years. Patients' mean duration of starting to HD varied between 7 to 54 months and the median duration of starting to HD was 11 months. When the etiologies were assessed; one (7.7%) patient had an unknown primary kidney disease, two (15.4%) focal segmental glomerulosclerosis (FSGS), one (7.7%) hyperoxaluria, one (7.7%) hypoplastic solitary kidney, two (15.4%) crescentic glomerulonephritis, three (23.1%) neurogenic bladder, two (15.4%) posterior urethral valve, and one (7.7%) reflux nephropathy. The median value of urine amount was 300 (10 - 1000) (mL/day), and 13 of 15 patients were using antihypertensive drugs. The demographic and clinical characteristics of the evaluated patients are shown in Table 1.

Table 1. Demographic characteristics of study group

Parameters	Frequency	Percentage (%)
Number of patients:	13	
Boys/Girls:	7/6	53.8/46.2
Age (years):	11,92±3,13 (5.7-16)	-
Height (cm):	137,92±22,37	-
Body mass index (kg/m2):	17,99±2,66	-
Body surface area (m2):	1,18±0,32	-
Dialysis duration (months):	11 (7-54)	-
Etiology of CRF:		
Unknown etiology	1	7,7
FSGS	2	15,4
Hyperoxaluria	1	7,7
Hypoplastic solitary kidney	1	7,7
Crescentic glomerulonephritis	2	15,4
Neurogenic bladder	3	23,1
PUV	2	15,4
Reflux Nephropathy	1	7,7
Urine amount (mL/day):	300 (10-1000)	
Number of antihypertensive drugs:	2 (0-3)	

CRF: Chronic renal failure, FSGS: Focal segmental glomerulosclerosis, PUV: posterior urethral valve

There were significant decreases in OH, Rel OH, ECF, and ECF/ICF values measured with BCM after HD (p=0.011, p=0.017, p= 0.037, p=0.05; respectively). There was no statistically significant change in TBF, ICF, LTM, BCM, and FAT values after dialysis. Pre-dialysis systolic blood pressure was decreased from 123±16 mmHg to 118 ± 12 mmHg after dialysis but it was not statistical significance (p=0,289) (Table 2).

The dry weights determined by pediatric nephrology specialists were higher than the weights calculated with BCM. There was a small, but significant difference between the mean values (34.71 ± 12.68 vs 33.71 ± 12.16 kg, Δ: 1 ± 1.51, p = 0.035) (Figure 1). A strong positive correlation of dry weight was found between BCM and clinical establishment (r = 0.993, p <0.001) (Figure 2).

Table 2. Evaluation of the changes in body fluid and blood pressure values measured pre- and post-hemodialysis

	Pre-hemodialysis	Post-hemodialysis	Change (Δ)	P avalues
OH (L)	1,78±1,72	0,81±1,96	0,96±1,15	0.011
Rel OH (%)	15,15±14,58	4,04±19,06	11,11±14,4	0.017
TBF (L)	21,48±8,37	20,43±7,61	1,04±2,96	0.227
ECF (L)	10,04±3,88	8,95±3,61	1,08±1,66	0.037
ICF (L)	11,42±4,77	11,47±4,41	0,05±1,74	0.925
ECF/ICF	0,89±0,18	0,79±0,21	0,11±0,17	0.05
LTM(kg)	25,24±11,04	25,74±10,79	0,64±1,87	0.261
BCM(kg)	13,97±6,59	14,33±6,63	0,29±0,99	0.333
FAT(kg)	7,52±4,43	6,45±4,41	1,01±3,11	0.286
SYSTOLIC BP (mm Hg)	123,7±16,95	118,4±12,14	5,23±17	0.289
DIASTOLIC BP (mm Hg)	77,69±11,66	79,23±13,21	1,53±11,4	0.636

Fluid load (OH)(L)), Relative fluid load (OH/ECF) (%), Total body fluid (TBF) (L), Extracellular fluid (ECF) (L), Intracellular fluid (ICF) (L), Ratio of ECF to ICF (ECF/ICF), lean tissue mass (LTM) (kg), body cellular mass (BCM) (kg) and total fat mass (FAT) (kg) BP: blood pressure
p≤ 0.05 was considered statistically significant.
Pa: comparison of pre- and post-dialysis values in hemodialysis group (Paired-Samples T test)

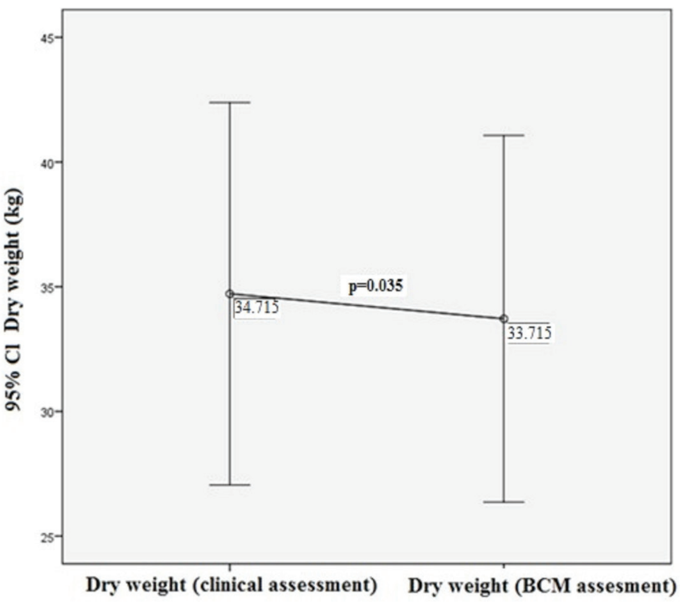

Figure 1. Comparison of the clinically determined dry weight and the dry weight measured using BCM

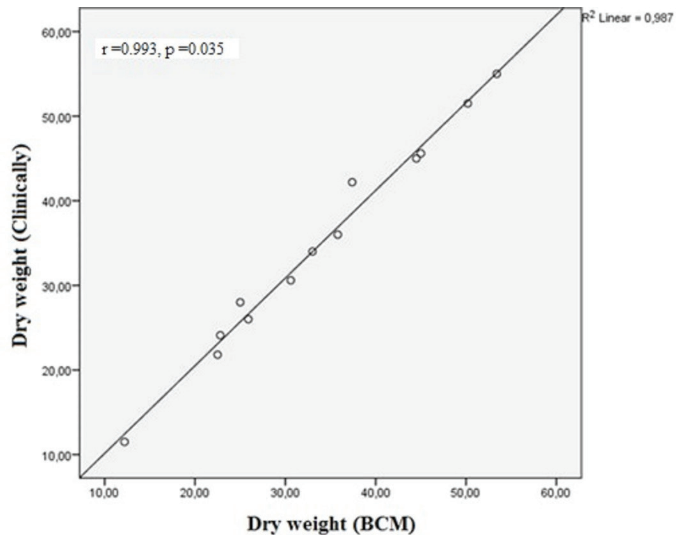

Figure 2. Correlation chart of the clinically determined dry weight and the dry weight measured using BCM

DISCUSSION

Dry weight is defined as the ideal weight at which the patient feels good, has a high exercise tolerance, and has no clinical signs of hypervolemia (4,8,11).

Most HD patients tend to gain weight and suffer hypervolemia between HD sessions due to low or no urine output. In general practice, overhydrating is clinically determined by nephrologists in HD patients, and the concept of dry weight has been suggested to determine an ultrafiltration target for dialysis therapy (4,11).

Multicenter studies have demonstrated the efficacy and safety of BCM Fresenius device using the method of multifrequency bioimpedance, in estimating fluid segments in the adults by comparing with gold standard methods (5,13-16,20,21). Wabel et al. (16) reported an excellent correlation between BCM measurements and gold standard reference methods in healthy individuals and HD patients. In a study by Caravaca et al. (22) evaluating the relationship between hypervolemia and hypertension with BCM technique in 175 pre-dialysis chronic kidney patients and BIS was reported to be a useful method to determine changes in hydration status.

Unlike these adult studies, a common standard could not be established on the bioimpedance based measurements during dialysis or being the most appropriate method to be involved in clinical decision-making in pediatric patients (23-26). Milani et al. (24) evaluated TBF and ECF with BCM, and bromide and deuterium dilution tests as the reference in 16 pediatric dialysis patients, and concluded that multi-frequency bioimpedance could not fully predict TBF and ECF in these young people. Conversely, Zaloszyc et al. (23) proposed the use of BCM in the body fluid measurement to support clinical symptoms in evaluating excessive hydration in pediatric dialysis patients. As far as we know, this is the first pediatric study in which the pre and post HD hydration status was assessed by the BIS method in Turkey.

In our study, BCM was performed before and after HD, and1) Significant decrease was observed in OH, Rel OH, ECF, ECF/ICF after HD,2) the clinically determined dry weight was significantly higher than the dry weight measured with BCM method, and a significant correlation was found between the two methods. Our findings were consistent with the studies that have used BIA in measuring dry weight of patients, and demonstrated that clinical dry weight is higher than the dry weight calculated with BIS method (27-29). The most important cause of this difference may be that nephrologist aim to achieve a slightly higher dry weight target, in order to safely attenuate hypervolemia by avoiding unpleasant hypovolemic consequences such as hypotension and cramps due to excessive fluid withdrawal in patients. Clinical evaluation is highly subjective and cannot accurately determine the volume hypervolemia in each patient, and these results in residual hypervolemia.

Inadequate evaluation of the extent of hypervolemia is a frequently encountered problem, especially since the majority of HD patients admitted to the hospital with the need for acute HD. Chronic hypervolemia can lead to hypertension or exacerbate the present condition, paving the way for severe pulmonary edema (30). Blood pressure is usually one of the clinical indicators used in the evaluation of hypervolemia in chronic HD patients (1-3). Katzarski et al. (17) compared pre and post-dialysis BIA measurement results of normotensive and hypertensive HD patients with the control group, and showed that the ECF was higher in hypertensive HD patients than in normotensive dialysis patients, and in normotensive patients compared to the control subjects. In our study, systolic blood pressure decreased after HD, but the mean systolic blood pressure after HD remained high. Use of the BCM can be helpful in discriminating whether hypertension should be treated by further reduction in overhydration or by antihypertensive agents, or accepted as being related to vascular stiffness.

The main limitation of our study is the small numbers of samples. Furthermore, data were collected in a single pediatric nephrology center and only hemodialysis patients were included. For the purpose of our study was no additional follow-up or gold standard measure of fluid overload. Namely deuterium dioxide dilution, was not used due to ethical concerns about repeated blood sampling in children. Notwithstanding these limitations, our data demonstrate clear potential of this straightforward bedside technique in quantifying fluid overload and optimizing target weight in this patient group.

As a result, even in a unit that gives a great attention to volume status, overhydration is seen when only routine tools are used to evaluate the volume status. In order to avoid an increase in residual hypervolemia between two nephrology evaluations, we suggest the routine use of BCM in dialysis units as a simple adjunct to the clinician in the follow-up of pediatric hemodialysis patients.

Competing interests: The authors declare that they have no competing interest.

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