

BCM – Body Composition Monitor: A New Tool for the Assessment of Volume-Dependent Hypertension in Patients on Maintenance Haemodialysis

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ABSTRACT

Hypertension is a common finding in end-stage renal disease patients with the prevalence between 20 to 85%. Although the etiology of arterial hypertension (AH) in this patient group is multifactorial, sodium and volume excess leading to extracellular volume overload are one of the most important and potentially adjustable causes. Control of volume status can either normalize the blood pressure (BP) or make the AH easier to control in the great majority of dialysis patients. Heavy reliance is placed on the dialysis procedure to gradually remove fluid over a period of days to weeks until a stable dry weight is achieved. Numerous attempts have been made to utilize alternative methods to more accurately assessment of dry weight, and the newest and most interesting method is multifrequency bioelectrical impedance spectroscopy (BIS). In this prospective study we used BIS in 65 haemodialysis (HD) patients in order to detect those with volume-dependent hypertension and to further investigate the role of dry weight management in BP control. Dry weight was corrected at the beginning, and after 1, and 3 months. Final data were collected after six months. Our data showed that assessment of fluid overload using BIS provides better management of fluid status and BP control in the patients on maintenance HD, and that dry weight correction can lead to significantly better control of volume-dependent hypertension in this patient group.

Key words: bioimpedance spectroscopy, body composition monitor, haemodialysis, hypertension, volume status

Introduction

Hypertension is a common finding in end-stage renal disease (ESRD) patients on maintenance dialysis. Based upon multiple studies from 25 to 85% of ESRD patients are hypertensive^{1,2}. The etiology of hypertension in ESRD is multifactorial³. Sodium and volume excess leading to extracellular volume overload are one of the most important and potentially adjustable causes. Poorly controlled hypertensive patients undergoing haemodialysis (HD) are more likely to have large interdialytic weight gain. Persistent hypertension in that group of patients often reflects volume control that remains imperfect^{4,5}. Chronic volume overload causes left ventricular hypertrophy, while dehydration can cause intradialytic adverse events, such a hypotension and cramps; both are linked to an increased morbidity and mortality in this patient

population^{6,7}. The diagnosis, objective quantification, and management of this problem is integral in attempting to improve clinical outcomes, including mortality and quality of life.

Control of volume status (VS) can either normalize the blood pressure (BP) or make the hypertension easier to control in the great majority of dialysis patients.

Heavy reliance is placed on the dialysis procedure to gradually remove fluid over a period of days to weeks until a stable dry weight is achieved⁸. Dry weight represent the lowest (post-dialysis) weight patient can tolerate without intradialytic symptoms or/and hypotension and in the absence of overt fluid overload⁹. Numerous attempts have been made to utilize alternative methods to

more accurately assess dry weight. These include measurements of the cardiothoracic index, inferior vena cava diameter, plasma natriuretic peptide concentrations, blood volume, and other parameters. However, these methods are frequently impractical, subjective, are not necessarily accurate, and a large prospective study has not yet been performed that compares these methods to clinical assessment alone^{10–13}. The clinician must therefore define the dry weight and goal BP for each dialysis patient based upon his or her best judgment and clinical experience.

The most interesting and brand new method for estimating VS, which is not in standard clinical practice yet, is multifrequency bioelectrical impedance spectroscopy (BIS). BIS measures at 50 frequencies (5 to 1000 kHz) covering the entire beta-dispersion information, determines the electrical resistances of the total body water and the extracellular water, and enables clear separation between extracellular and intracellular water by the extremely wide range of measurement frequencies.

The aim of this prospective study was to detect HD patients with volume-dependent hypertension by BIS, and to further investigate the manner in which correction of volume overload can change BP in these patients.

Patients and Methods

The present prospective study was conducted from 1 November 2012 to 1 May 2013, at the Department of Nephrology and Dialysis, Clinical Hospital Center Rijeka, Croatia. The study involved all ESRD patients on maintenance HD for at least six months, three times a week, four hours each treatment on biocompatible synthetic (polysulfone) high-flux membranes. All patients were older than 18 years, and signed the informed consent approved by the local Ethics committee. Patients who have been on peritoneal dialysis or transplanted before start of HD, patients with clinical and laboratory signs of local or systemic inflammation, malignant disease, patients with permanent cardiac electrostimulator or defibrillator, pregnant or breastfeeding women, patients with overt heart failure (NYHA grade 3 and 4) and patients with one or more limb amputations were not included in the study.

VS was assessed using a BIS method. Measurements were performed using a Body Composition Monitor (BCM – Body Composition Monitor, Fresenius Medical Care, Bad Homburg, Germany), before the midweek HD session at months 0, 1, 3 and 6 by experienced medical nurse. BIS measurement was performed with the patient in a supine recumbent position. After disinfection of patient's fist and foot on the same body side, electrodes were placed. Red and black electrodes were put on the fist and same two on the foot, having in mind that red electrodes always went distal. After that, patient was connected to the BCM device and the measurement of about three minutes was performed. The values of overhydration, extracellular water, intracellular water, total body water, lean and adipose tissue mass were collected.

Results were taken as valid only if this operating quality score was over 90%.

Experienced medical nurse measured at the beginning and at the end of midweek HD session BP at months 0, 1, 3 and 6. The same day VS was assessed by BCM. Standardized Omron electronic BP monitor (Omron M6; Omron Health Care Europe, Milton Keynes, UK) with brachial cuff adjusted to the patient's brachial circumference was used for all measurements within the study. BP was measured after patient's repose in duration of 10 minutes in sitting position by taking measures three times in a row, and the arithmetic mean for systolic (BP_{sys}) and diastolic BP was taken as a final value.

Dry weight was defined as the lowest weight a patient can tolerate without the development of symptoms or hypotension and according to cardiothoracic index and clinical status¹⁴. The body weight before HD treatment, and average daily diuresis were noted from the patient's HD record at the BCM and BP measurement day. Dialysate sodium was adjusted to 140 mmol/l in all patients. Patients with fluid overload more than 2.5 liters were considered as hypervolemic, and those with fluid deficiency more than –1.1 liters as hypovolemic. Patients with systolic BP over 140 mmHg were considered as hypertensive, and those with BP_{sys} less than 100 mmHg as hypotensive.

The data were used to generate a graphical tool, hydration reference plot (HRP), which allows rapid differentiation between hypotensive and hypertensive patients as well as distinguishing fluid overload from the state of normohydration. Depending on the BP and VS patients were divided into five groups. The group one consisted of patients with volume-dependent hypertension (BP_{sys}>140 mmHg, OH>2,5 L), group two of patients with hypertension and normal volume status (BP_{sys}>140 mmHg, OH<2,5 L), group three consisted of hypovolemic and hypotensive patients (BP_{sys}<100 mmHg, A OH<–1,1 L), group four of hypervolemic but normotensive patients (BP_{sys}<140 mmHg, A OH>2,5 L), group five of normovolemic – normotensive patients (BP_{sys}<140 mmHg, OH<2,5 L). According to achieved data dry weight and ultrafiltration rate at month 0, 1 and 3 were corrected. As patients serve as their own controls, no normal values derived from healthy populations have to be used for dry weight assessment. In the group two the antihypertensive therapy was modified according to the current guidelines.

Statistics

Statistical analysis of data was performed using descriptive statistics (mean and standard deviation). Categorical variables were tested by chi-square test. Testing the difference of two independent groups was performed using t-test and ANOVA. P-value <0.05 was considered to be statistically significant. Statistical analysis was made using MedCalc statistical software package, version 10 (MedCalc, Mariakerke, Belgium).

Results

In the present study, 65 ESRD patients (36 male and 29 female) on maintenance HD mean age 61.1 ± 13.9 years met inclusion criteria and were analyzed. The most common etiology of ESRD in the included population was non-diabetic nephropathy of vascular origin due to arterial hypertension (28%). At the beginning of the study 49.2% of patients were normotensive (mean BP_{sys} was 123 ± 11 mmHg) and 50.8% were hypertensive (mean BP_{sys} 156 ± 15 mmHg). After the follow-up of six months 78.5% were normotensive (mean BP_{sys} 128 ± 16 mmHg; $p < 0.0001$) and 21.5% were hypertensive (mean BP_{sys} 142 ± 19 mmHg; $p = 0.03$). Although higher levels of hemoglobin (Hb) could contribute to higher BP we found neither significant difference in Hb levels after six months and correlation between Hb levels, BP or hydration status (data not shown). There were also no correlations between subgroups of patients based on the etiology of ESRD, BP and VS. Table 1 provides a description of the demographic characteristic of the 65 analyzed HD patients as well as comparison of data obtained on month 0 and 6.

On the first place, we were interested to detect those patients that have volume-dependent hypertension since correction of VS should lead to the better control of BP. To that aim we assessed VS by BIS measurements and data were interpolated with data on BP monitoring, as we described in »Patients and Methods« section. Based on these data patients were placed into five categories (Figure 1). In the volume-dependent hypertension group (group I) there were 22.5% patients while in the normovolemic hypertensive group (group II) there were 31% of patients. Interestingly, there were no patients that fit in the group III (hypovolemic and hypotensive patients). There were only 9.5% of hypervolemic but normotensive

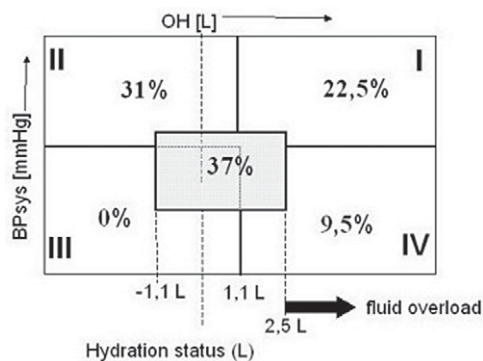


Fig. 1. Hydration reference plot of 65 haemodialysis patients at the beginning of the study. The regions within the plot allow differentiation between normotensive, hypotensive, and hypertensive patients as well as distinguishing fluid overload from the state of normohydration. I – volume-dependent hypertension (BP_{sys} > 140 mmHg, OH > 2,5 L), II – hypertension and normal volume status (BP_{sys} > 140 mmHg, OH < 2,5 L), III – hypovolemic and hypotensive patients (BP_{sys} < 100 mmHg, OH < -1,1 L), IV – hypervolemic but normotensive patients (BP_{sys} < 140 mmHg, OH > 2,5 L), V – normovolemic – normotensive patients (BP_{sys} < 140 mmHg, OH < 2,5 L).

TABLE 1
DEMOGRAPHIC CHARACTERISTICS OF THE 65 PATIENTS ON MAINTENANCE HAEMODIALYSIS

Characteristic		p
Gender (M:F)	36:29	NS
Age (years)	65.1 ± 13.9	
Etiology N (%)		
Nondiabetic nephrop*	18 (28)	
Diabetic nephropathy	14 (22)	
Glomerulonephritis	12 (18)	
Interstitial nephritis	10 (15)	
Polycystic kidney disease	6 (9)	
Other	5 (8)	
X ± SD		
Weight (kg)	0 = 73.8 ± 17.3 6 = 72.4 ± 16.9	0.03
Dry weight (kg)	0 = 71.5 ± 16.6 6 = 70 ± 16.4	0.02
Hemoglobin (g/L)	0 = 111.8 ± 9.3 6 = 113 ± 5	0.38
Overhydration (L)	0 = 1.73 ± 1.75 6 = 1.12 ± 1.13	0.004
Predialysis BP (mmHg)	0 = 140 ± 21 6 = 130 ± 17	<0.0001
Postdialysis BP (mmHg)	0 = 130 ± 21 6 = 121 ± 14	0.002

* nondiabetic nephrop – non-diabetic nephropathy of vascular origin, BP – blood pressure; The clinical data are obtained at the beginning of the study, and after the follow up of six months.

patients (group IV) and 37% of patients were normovolemic and normotensive (group V).

Next we were interested whether modification of dry weight can lead to better control of hypertension espe-

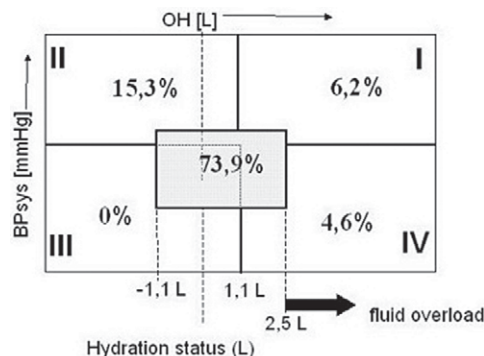


Fig. 2. Hydration reference plot of 65 haemodialysis patients after six months. I – volume-dependent hypertension (BP_{sys} > 140 mmHg, OH > 2,5 L), II – hypertension and normal volume status (BP_{sys} > 140 mmHg, OH < 2,5 L), III – hypovolemic and hypotensive patients (BP_{sys} < 100 mmHg, OH < -1,1 L), IV – hypervolemic but normotensive patients (BP_{sys} < 140 mmHg, OH > 2,5 L), V – normovolemic – normotensive patients (BP_{sys} < 140 mmHg, OH < 2,5 L).

cially in the volume-dependent hypertension patients. According to data of VS obtained by BIS and BP data, dry weight and ultrafiltration rate were corrected at month 0, 1 and 3 (data not shown). After the six months we performed final measurements that were compared with the initial data. The data are depicted on the figure 2. In the group I and II there were statistically significant decrease of patients: -16.3% for group I ($p=0.04$) and -15.7% ($p=0.03$). The reduction of patients in the hypervolemic normotensive group was -4.9% but this was not statistically significant ($p=0.9$), while in the fifth group there were 36.9% patients more and this was highly statistically significant ($p<0.0001$).

Discussion

The purpose of this study was to evaluate BIS method as a tool in detection of volume-dependent hypertensive patients on maintenance hemodialysis. Furthermore, by using the data on overhydration obtained with BIS we want to intervene in fluid overloaded patients in order to achieve better dry weight and BP control.

Assessment of dry weight in everyday clinical practice is mainly based on the assessment of cardiothoracic index, peripheral edema, and clinical status of the patient but these are very subjective and often not accurate evaluation methods. Numerous attempts have been made to utilize alternative methods to more accurately assess dry weight. Therefore, there is a lot of effort in developing, testing and validation of new, more useful and precise methods. Several new methods for determination of dry weight based on bioelectrical impedance have been developed in recent years. Although none of these methods has been widely used in clinical practice so far, BIS has been the most promising novel technique used for dry weight determination, and BP control in dialysis population group^{15,16}.

Based on the BP values and BIS data on overhydration we were able to stratified patients into five groups according to previously published study¹⁷. The vast majority of patients were hypertensive and 22.5 % of all patients appeared to have volume-dependent hypertension. That was more in comparison to previously mentioned study by Wabel et al where just 15% of studied HD patients had volume-dependent hypertension. Greater proportion of patients (31%) were hypertensive but norm hydrated indicating that hypertension in the ESRD population was not exclusively volume-dependent,

and could represent essential hypertension, as shown in the study of Kooman JP et al.¹⁸. One of the reasons for the high prevalence of arterial hypertension in dialysis patients might be the way physicians treat arterial hypertension once it has been diagnosed. It is also worth noting that 9.5 % of studied patients were overhydrated but normotensive.

The HRP we used, provided an invaluable tool for classifying patients in terms of BPs and VS, and the proximity of these parameters to reference ranges¹⁹. These both were effective, useful and safe tools for estimating the right modality of BP control in these patient groups.

By modifying dry weight by ultrafiltration on month 0, 1, and 3 we were able to obtain statistically significant reduction of proportion of patients have been in volume-dependent hypertension group. However, after six months there were still 6.5% patients that have volume-dependent hypertension independently of our effort to achieve dry weight. These were group of uncooperative patient that had usually more than four kilogram of interdialytic weight gain. Once we have identified patients with volume-dependent hypertension, we were able to maintain dry weight in norm hydrated hypertensive patients and to achieve better BP control by modification of antihypertensive therapy. By this approach, we were able to halve this group of patients. Interestingly, although not statistically significant, we were also able to reduce the proportion of patients within overhydrated normotensive group by raising their dry weight while still preserve normal BP.

Limitations of our study were the small number of enrolled subjects and the heterogeneity of the studied group.

Conclusion

Our data showed that assessment of fluid overload using BIS provides better management of fluid status and BP control in the patients on maintenance HD. It is safe, reproducible and objective tool that should restrict the practice of probing dry weight in HD patients. Once dry weight can be reliably and reproducibly determined by bioimpedance technology, BCM may become also a powerful tool for BP control during HD. Further refinement of the methods as well as large-scale clinical studies to demonstrate the accuracy of objective dry weight measures, and to prove the long-term clinical value of dry weight achievement, are needed.

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»BCM – BODY COMPOSITION MONITOR«: NOVI UREĐAJ ZA DIJAGNOSTIKU HIPERTENZIJE OVISNE O VOLUMENU U BOLESNIKA NA REDOVITOJ HEMODIJALIZI

SAŽETAK

Hipertenzija je čest nalaz u bolesnika u završnom stadiju kronične bubrežne bolesti s učestalošću od 20 do 85%. Iako etiologija nastanka arterijske hipertenzije u toj skupini bolesnika ovisi o više čimbenika, višak vode i soli vodi u hipervolemiju. Na navedene čimbenike, s druge strane, možemo najlakše utjecati te ih korigirati. Korekcijom volumnog statusa (VS) možemo normalizirati krvni tlak (KT) ili ga barem lakše kontrolirati u većem broju bolesnika na redovitoj hemodijalizi (HD). U većini slučajeva se oslanjamo na sam HD postupak putem kojeg postepeno uklanjamo višak tekućine tijekom nekoliko dana do tjedana, sve dok ne postignemo suhu težinu. Postoji nekoliko metoda kojim se pokušava što preciznije odrediti suhu težinu, a najnovija i najinteresantnija među njima je metoda multifrekvencijske bioimpedancijske spektroskopije. U našem prospektivnom istraživanju smo primjenili navedenu metodu u 65 HD bolesnika da bi dijagnosticirali povišeni KT ovisan o volumenu te da bi preciznije odredili suhu težinu zbog njegove bolje kontrole. Suhu težinu smo nakon mjerenja korigirali na početku te nakon jednog i tri mjeseca. Zadnje mjerenje smo učinili nakon šest mjeseci. Naši su podatci pokazali da korekcija VS uz pomoć multifrekvencijske bioimpedancijske spektroskopije omogućava bolju kontrolu VS i KT u bolesnika na redovitoj HD. Korekcija suhe težine uvjetuje bolju kontrolu hipertenzije ovisne o volumenu.