Journal of Nephrology & Therapeutics

Rashawn et al., J Nephrol Ther 2016, 6:6
DOI: 10.4172/2161-0959.1000274

Research Article

OMICS International

Chest Ultrasound, Body Composition Monitoring and Brain Natriuretic Peptide for Assessment of Hydration Status in Hemodialysis Patients. (Single Center Experience)

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Received date: November 28, 2016; **Accepted date:** December 5, 2016; **Published date:** December 10, 2016

Abstract

Objective: Normal hydration state without experiencing symptoms indicative of over or under hydration at or after the end of hemodialysis treatment or what we call "dry weight" DW is a challenge for most nephrologists. Different methods has been tried to achieve this goal. We performed this study to investigate and compare three different objective tools (2 medical devices and 1 laboratory value) body composition measurement (BCM), chest ultrasound and brain natriuretic peptide (BNP) to narrow the gap toward proper estimation of DW in Hemodialysis patients.

Methods: 49 stable chronic hemodialysis patients underwent assessment pre and post hemodialysis using all the available modalities mentioned above.

Results: BCM assessment showed pre dialysis 27 patients (55%) were classified as overhydrated, 18 patients (37%) as normohydrated and 4 patients (8%) patients as hypohydrated. Lung comets score before hemodialysis were 21.4 ± 17 and after hemodialysis were 9.1 ± 6.9. 19 patients (39%) had lung comets score <14, 21 (43%) between 14-30 and 9 (18%) >30. There was no difference in age, gender, SBP, and DBP between the three groups. Circulating BNP levels showed significant decrease (33%) from a mean of 10443 ± 17232 pg/ml predialysis to 6956 ± 13885 pg/ml post-dialysis (p=0.00).

Conclusions: Chest ultrasound, BCM, and BNP measurements as indicators for volume status assessment showed significant reduction in overhydration after dialysis, which is related more to changes in volume status rather than to its absolute values before and after hemodialysis however the was no correlation between the three modalities as assessment tool for volume status

Keywords: Dry weight; Chest Ultrasound; Body composition measurement; Brain natriuretic peptide; Hemodialysis

Introduction

Accurate assessment of volume status is essential in patients undergoing hemodialysis. Persistent hypervolemia in these patients will lead to uncontrolled hypertension, left ventricular hypertrophy and progression to congestive heart failure. Large volume interdialytic weight gain in addition to a persistent hypervolemic status will further project a burden on the cardiovascular system [1]. Management of volume status requires accurate assessment of hydration status in addition to fluid and salt restriction. DW assessment and establishment is a challenge for most nephrologists. Clinically, dry weight is determined as the lowest weight a patient can tolerate without developing intra or interdialytic symptoms. If this is achieved the patient will be as close as possible to a normal hydration state without experiencing symptoms indicative of over or under hydration at or after the end of hemodialysis treatment .

Dry weight can be evaluated clinically but this is not sensitive as fluid may accumulate by several liters in the body before edema becomes clinically evident [2]. Inaccurate dry weight assessment can be overestimation or under estimation. Overestimation will lead to hypertension; around 80% of all hypertension in dialysis patients is due to chronic hypervolemia [3-5]. In dialysis patients hypertension has been linked to excess cardiovascular and cerebrovascular adverse events which are the most common cause of morbidity and mortality in this population [6]. Chronic hypervolemia also will lead to left ventricular hypertrophy (LVH), which is associated with higher incidence of myocardial infarction, congestive heart failure, and sudden death [7-9]. On the other hand, under estimation of the dry weight lead to frequent hypotensive episodes which will lead to patient dissatisfaction with the dialysis prescription, early withdrawal from dialysis, and frequently interrupted sessions, all of which lead to inefficient dialysis, poor nutritional status, and poor outcome.

Several have looked at different methods to accurately assess volume status [10]. An ideal method should be highly sensitive, specific, readily available, inexpensive, quick and easy to use by clinicians. Unfortunately, such a method still does not exist. Many objective techniques of assessing hydration status have been proposed, each of these having its own advantages and limitations. These methods can be done through devices like body composition monitoring (BCM), ultrasound (Chest ultrasound) or biomarkers such as natriuretic peptides (B-type natriuretic peptide, BNP). In BCM, bioelectrical impedance analysis estimates body composition including total body, extracellular and intracellular water [8,9]. In chest ultrasound, hydration status can be correlated to score of B-lines, B-lines are multiple comet tails originating from the water-thickened interlobular septa has a linear correlation with the extravascular lung water and provides useful information about hydration status of the patient. BNP is a peptide synthesized and stored in cytoplasmatic vesicles of myocytes; its levels rise with ventricular stretch, caused by pressure or volume overload [10].

The aim of this study is to evaluate the 3 different methods as a tool for assessment of hydration status and find if there is a correlation among them. Many studies have showed that most of dialysis patients still have excess ECV even after their clinical dry weight has been achieved [11,12]. In a study of 121 patients where bioimpedance was used to adjust the prescribed dry weight; blood pressure control in hypertensive patients with excess ECF was readily achieved [11].

Materials and Methods

Patient characteristics

We performed a cross-sectional prospective observational study of 49 dialysis patients who met our inclusion criteria (age greater than 18 years at the time of the study and on chronic hemodialysis for at least 3 consecutive months) at the hemodialysis unit of King Faisal specialist hospital and research center, Riyadh, Saudi Arabia during the period between March 2015 and September 2015. The protocol of this study was approved by our office of research affairs. All patients who participated in the study gave their informed consent prior to starting the study. Exclusion criteria were patients Known to have interstitial lung disease by previous CT scan were excluded because of pulmonary fibrosis might interfere with lung ultrasound comet scores [13], patients with low ejection fraction <40% by echocardiography, or pericardial effusion, Patients with acute illness within 3 months before the study and patients with metallic joint prosthesis or pacemakers as they can interfere with BCM.

Treatment protocols

All patients were treated thrice weekly. Dialysis performed using (Fresenius Medical Care type 5008 CorDiax machine), average time of dialysis was 240 minutes per session using high-flux Fresenius polysulfone membrane dialyzers (FX class), dialysate flow rate of 800 ml/min, dialysate sodium concentrations of 135-138 mmol/l, dialysate calcium concentrations of 1.25 mmol/l, potassium concentration ranging from 2-3 mmol/L, bicarbonate concentration of 35 mmol/L, blood flow rate ranging from 400-450 ml/min.

Fluid overload was considered as weight gain from the estimated dry weight based on clinical patient parameters such as body weight, blood pressure, presence of edema and vascular congestion by chest X-ray. All patients were evaluated at the bedside by BCM and lung ultrasound before and after hemodialysis (last dialysis session of the week). Blood samples for BNP, were withdrawn for all patients before and after hemodialysis.

BCM assessment

BMC method: While patient is in supine position we used two electrodes to non-fistula forearm, one on the dorsal surface of the hand and the other electrode (proximal) on an imaginary mid-line crossing the wrist bone. Another two electrodes on the ipsilateral ankle, one on the dorsal surface of the foot across the knuckles of the toes, the other electrode (proximal) along an imaginary mid-line through the ankle. All measurements were performed by a trained physician and a dialysis nurse. The hydration state was assessed by portable whole Body Composition Monitor device (BCM, Fresinus Medical Care AG & CO KGaA OP 3/12.07, Homburg, Germany) this was done prior to and within 30 minutes after the end of the dialysis session.

Overhydration (OH) is a component of extracellular volume, and therefore it is a part of extracellular water the BCM device calculates the OH based on measurements values, using a physiological model. Pre hemodialysis we classified patients according to their hydration state (HS) into three categories hypohydrated, normohydrated, and hyperhydrated (HS, <-0.5 liters, -0.5 liters ≤ 0.5 liters, and > 0.5 respectively). We have calculated the residual overload by calculating the difference between hydration state (measured by BCM before hemodialysis), and fluid loss during hemodialysis, post hemodialysis we classified patients according to their residual overload as overhydrated or non-overhydrated (residual overload >0.5 and ≤ 0.5 liters respectively).

Chest ultrasounds

Chest US for all patients were performed by a trained emergency physician who had experience with lung ultrasound techniques including recognition and interpretation of ultrasound lung comets or B-lines. Scans were performed using commercially available portable ultrasound equipment, 3.5 C, 3.5-11.5 MHz Convex transducer probe (General Electric Health Care) within 10-15 minutes before starting hemodialysis, and 20-30 minutes post dialysis. The assigned physician performed chest US in the parasternal, midclavicular, anterior axillary and midaxillary lines of the second to fifth intercostal spaces on the right side and second to fourth spaces on the left side for a total of 28 positions per each examination. Previous reports had validated this technique as diagnostic and prognostic end points and for correlation with extravascular lung water [13].

B-lines are echogenic, dynamic, wedge-shaped signal, they have narrow origin in the near field of the image, coming from the pleural line and extending to the edge of the screen. B-lines score (BLS) is defined as the sum of all recorded B-lines were counted and recorded for each time point on a data collection sheet; their sum yielded the overall BLS, [14] (a limit of <8 lung comets were considered normal). On the basis of this score, we divided the patients into the following 3 categories of overhydration severity: mild overhydration with8-13lung comets, moderate overhydration with 14-30 lung comets, and severe overhydration with >30 lung comets [13].

Statistical analysis

Statistical software SPSS 16.0 was employed for statistical analysis. Continuous/quantitative variables are summarized as mean ± SD. These variables were comparing by student's t-test. Correlations between different variables were done by Pearson product moment correlation coefficient, a two-sided $p<0.05$ was considered to be statistically significant.

Results

Predialysis findings

49 patients were evaluated (51% females) with a mean age of 47 ± 18 years. The demographic and clinical characteristics of the study population are shown in Table 1. Based on individual hydration state measurements according to BCM analysis, 27 patients (55%) were classified as overhydrated, 18 patients (37%) as normohydrated and 4 patients (8%) patients as hypohydrated. With regard to age, gender and blood pressure, we did not find significant difference between the hyper hydrated, normohydrated, or hypo hydrated group.

	Mean	SD
Age	47	18
BMI	22.9	5.6
Pre HD SBP	142	26.7
Pre HD DBP	72	16.4
Post HD SBP	129	22.8
Post HD DBP	65	16
HTC Pre	0.295	0.031
HTC post	0.326	0.047
BNP Pre	10443	17232
BNP Post	6956	13885
Prescribed DW	57.3	20.4
Pre HD weight	58.8	20.7
Post HD weight	57.2	20.3
Net UF	1.6	0.9
BCM DW	57.3	20.3
US B-lines Pre HD	21.4	15.9
US B-lines Post HD	9.1	6.9

Table 1: Demographic and clinical characteristics of the study population.

All 49 patients were able to finish complete lung US with 100% feasibility. The duration of US examination for each patient ranged from 10 to 15 minutes' (average 12 minutes). Our data showed that the mean and median numbers of lung comets score before hemodialysis were 21.4 ± 15.9, (median 17) and after hemodialysis were 9.1 ± 6.9, (median 7). 19 patients (39%) had lung comets score <14, 21 patients (43%) between 14-30 and 9 patients (18%) more than 30. There was no significant difference in age, gender, SBP, and DBP between these three groups.

We found that out of 27 patients classified as overhydrated by BCM, only 4 patients were severely congested by lung comets score, and out of 18 patients classified as normohydrated by BCM, 5 patients (27%) showed moderate to severe pulmonary congestion by lung comets score, there was no significant correlation between the 2 modalities as assessment tool for hydration status before hemodialysis (r=-0.04, p<0.826).

Post-dialysis findings

In our patients the mean body weight decreased from 58.8 ± 20.7 kg predialysis to 57.2 ± 20.3 kg post dialysis, the difference was significant with (p<0.000). Using the post-dialysis BCM data, 28 patients (57%) were hypohydrated, 12 patients (24%) were normo-hydrated, and 9 patients (18%) were still hyperhydrated. 10 patients had residual overload more >0.5 L most likely because they did not tolerate fluid removal. Pearson Correlation between clinically estimated DW and BCM dry weight was (r=0.98) with a p value of <0.000 at 95 % confidence interval. Suggesting that both clinically estimated DW and BCM DW were in full agreement.

In patients with lung volume overload detected by ultrasound pre-dialysis, 21 patients (70%) had improvement in pulmonary congestion and moved from overhydration category to normal or hypohydration category. The proportion of patients with absent or mild pulmonary congestion was 40 patients (82%), 9 patients (18%) with moderate pulmonary congestion and non with severe lung congestion. We observed better association between lung comets score and the fluid status by BCM: among patients who were normohydrated post-dialysis, (n=12), three patients (25%) had a BLS>14. Interestingly there was significant correlation between predialysis BLS and the reduction in this score post dialysis (p=0.000). The decrease in BLS post hemodialysis was independent of changes in systolic and diastolic blood pressures, BCM data or changes in the circulating BNP.

Circulating BNP levels showed significant decrease (33%) from a mean of 10443 pg/ml (± 17232 pg/ml) predialysis to 6956 pg/ml (± 13885 pg/ml) post-dialysis (p=0.00).. So we have found that the measurements of the fluid status by BCM, lung ultrasound and BNP (mean, SD) dropped significantly posthemodialysis Tables 2A and 2B and Figures 1 and 2. =

Pre Hemodialysis	Post Hemodialysis
39	82
43	18
18	0

Table 2A: Comparing US-B lines Pre vs. Post Hemodialysis (p=0.000).

BCM (%)	Pre Hemodialysis	Post Hemodialysis
Dehydrated <-0.5 L	8	57
Norm hydrated -0.5 ≤ BCM pre HD/HS ≤ 0.5	37	24
Overhydrated >0.5 L	55	18

Table 2B: Comparing BCM Pre *vs.* Post Hemodialysis (p=0.000).

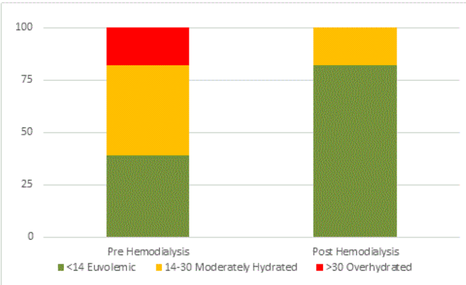

Figure 1: Hydration status pre *vs.* post hemodialysis using B-Line Scores with chest ultrasound.

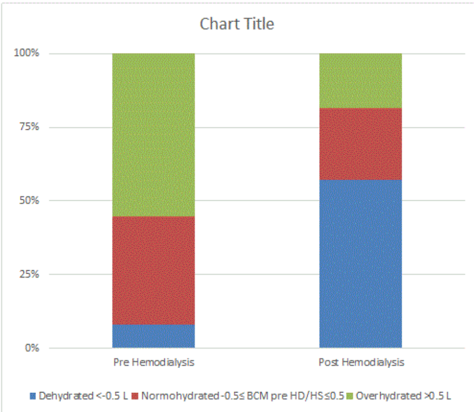

Figure 2: Hydration status pre *vs.* post using body composition measurement.

Pre Hemodialysis	US-B Lines	BNP	BCM
BCM	0.98	0.07	-
	0.594	0.631	-
BNP	0.13	-	-
	0.939	-	-
US-B Lines	-	-	-
	-	-	-
Post Hemodialysis	US-B Lines	BNP	BCM
BCM	0.134	1	-
	0.358	0.115	-
BNP	0.145	-	-
	0.32	-	-
US-B Lines	-	-	-

Table 3: Correlation between different techniques pre and post hemodialysis.

However, we did not find significant correlations among the three techniques for fluid status assessment either pre or post dialysis (Table 3). Mean SBP prehemodiaysis was 142 (± 26.7) mmHg, and the mean DBP was 72 (± 16.4) mmHg. Mean SBP posthemodiaysis was 129 (± 22.8) mmHg, and the mean DBP was 65 (± 16) mmHg, there was a statistically significant difference between both SBP and DBP ($p<0.00$).

Discussion

The determination of a euvolemic status or dry body weight assessment in hemodialysis patients is not easy to achieve, there is no gold standard method for that assessment. Clinical assessment techniques like detection of lower limb edema, raised JVP or chest auscultation and Blood pressure measurement are subjective and unreliable markers of intravascular volume especially in stable chronic dialysis patients [14]. Previous studies had demonstrated that hydration state is an important and independent predictor of mortality in chronic hemodialysis patients [15]. We compared three different objective tools of hydration state assessment before and after hemodialysis, and if they are similar or superior to clinically determined dry weight. In the current study we have used lung ultrasound, BCM, and (NT proBNP) for all patients at the same time pre and post hemodialysis, to quantify the volume statuses. All of them showed reduction in hyperhydration state after hemodialysis.

BCM and dialysis: There was a significant reduction in overhydration state post hemodialysis. We showed that both BCM dry weight and clinically estimated dry weight were significantly correlated. We have performed BCM prehemodialysis and 30 minutes post hemodialysis. Previous studies used BCM either immediately pre or at different time points post hemodialysis or in non-dialysis day, there was neither consensus nor special indication about the best time to perform BCM [16-19]. BCM can be performed anytime during 2 hours post hemodialysis and comparable results will be obtained provided that the hydration status is constant (no drinks or food) [20]. Severe skin lesions, morbid obesity, and unfitting or wrongly positioned electrodes are considered practical limitations for dry weight assessment by BCM; [21] however with all of these limitations; BCM is a fasible easy, reproducible technique. BCM might be a useful tool in measuring the volume state in dialysis patients in conjunction with clinical judgment.

Chest Ultrasound: The concept of lung ultrasonography is that normally aerated lung does not transmit sound, but wet lung leads to appearance of B-lines as sound is transmitted through these congested spaces and reflected between the walls of interstitium.[22] The interpretation of lung ultrasound is simple, the dry lung is "black", wet lung is "black-and white" (white stripes representing lung comets), and frank pulmonary edema lung is "white" (no air, only water). Dialysis patients develop pulmonary congestion and increased lung water as their extracellular volume expands. An important inquiry is over how long is these B lines appear and disappear with changes in the volume status in dialysis patients. Patients with low percentage or absence of B-lines score before hemodialysis most likely they are at the euvolemic side. Mallamaci et al. [16] used same technique in a population of 75 HD patients to estimate the prevalence of pulmonary congestion and its reversibility after dialysis. They concluded that chest US can detect pulmonary congestion at pre-clinical stage, they found that in their study that up to 57% of asymptomatic dialysis patients had moderate to severe congestion. Also Noble et al observed that in 40 dialysis patients, disappearance of B line happened in real time during ultrafiltration [22]. Thus, quantification and detection of B-lines in dialysis patients is very important as it might help to identify early signs of fluid overload even in asymptomatic patients. In this study we found a significantly lower percentage of BLS immediately post hemodialysis, and therefore the resolution of B-lines happened over the duration of dialysis when excess fluid was removed

So lung ultrasound can be used as is reliable tool for assessing volume status during hemodialysis.

BNP: BNP is one of the natriuretic peptides and it is composed of 32 amino acids, 3.5 kDa of molecular weight with a 15-20 min half-life [23]. It is a vasodilatory cardiac neurohormone mainly released from the ventricles secondary to volume or pressure overload. The two main causes of high level of BNP in dialysis patients are heart failure with altered ventricular function and volume overload. In the first cause circulating BNP level is not easily reversible, but it is reversible by ultrafiltration in dialysis patients [24] studies reported that dialysis patients without cardiac disease or left ventricular hypertrophy have BNP levels similar to control subjects [25]. However in dialysis patients with high BNP levels, this might be due to the uremic cardiomyopathy rather than the renal impairment itself [26]. In our study we have found that dialysis patients without Hear failure (echocardiography done within 6 months before) the study, 48 patients 98% of them had a high (>400 pg/mL) plasma BNP level. We didn't categories the patient's volume status according to the level of BNP as there was no reference for that but overall there was a significant decrease in BNP levels post hemodialysis, (although many patients had readings >400 pg/ml), the difference between pre hemodilysis and post hemodialysis readings was statistically significant ($p<0.000$). In our opinion the predialysis circulating levels of BNP are related to cardiac strain (stretch) by fluid overload pre-dialysis, fluid removal will lead to drop in its level. The level of BNP may be used in the future to categories the patient's volume status (hyperhydration normhydration hypohydration).

Though the three modalities, all showed correlation with fluid removal in dialysis patients, we did not find significant correlation between circulating BNP levels, lung comets score and or hydration state by BCM either pre or post hemodialysis as modality for assessment of hydration status. This stand in contrast to the results of another study [27] which showed a fair correlation between the three different techniques. The discrepancy in results between these studies might be due to different sample size, and the population studied.

Limitations of the study include relatively small number of patients from a single dialysis center. Although the physician who did the ultrasound was blinded to the BCM results they were not blinded to timing of measurements (pre and post-dialysis). Larger multicenter studies assessing the value of chest ultrasound in clinical decision making are needed to solidify its usefulness, and its clinical application.

This study is the first one from our area to compare three different objective tools for volume status assessment. We can conclude that the three techniques used for volume status assessment showed significant reduction in overhydration after dialysis, which is related more to changes in volume status rather than to its absolute values before and after hemodialysis. Improved association between lung comets score and measurements of fluid status by BCM was appreciated only after hemodialysis.

Acknowledgments

We would like to acknowledge Cyrus C Custodio, Saw Bee Chin and Maria Cecilia for their contribution towards this study.

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