Evaluation of Nutritional Status and Hydration in Patients on Chronic Hemodialysis by Bioelectrical Impedance Analysis

Antonios H. Tzamaloukas[1], Emmanuel I. Agaba[2], Aideloje Onime[1], Dorothy J. VanderJagt, PhD[3], Irene Ma[3], Andrea Lopez[3], Raymond Martinez[3], Rolinda A. Tzamaloukas, RN[4], Robert H. Glew, PhD[3]

[1] Department of Medicine, New Mexico Veterans Affairs Health Care System and University of New Mexico School of Medicine, Albuquerque, New Mexico, USA; [2] Department of Medicine, Faculty of Medical Sciences, University of Jos, Jos, Plateau State, Nigeria; [3] Department of Biochemistry and Molecular Biology, University of New Mexico School of Medicine, Albuquerque, New Mexico, [4]Private Practice Nursing, Albuquerque, New Mexico, USA

Corresponding author: **Robert H. Glew, PhD.**
Department of Biochemistry and Molecular Biology, University of New Mexico School of Medicine, MPC08 4670, 1 University of New Mexico, Albuquerque, NM 87131-0001, USA.
E-mail: rglew@salud.unm.edu; FAX: 001-505-272-6587

Abbreviated title: Nutrition and hydration in hemodialysis

Abstract

Background: Nutrition and hydration of the dialysis patients have major influences on the outcomes of chronic hemodialysis.

Purpose: To characterize the states of nutrition and hydration in patients on chronic hemodialysis at Jos University Teaching Hospital (JUTH) and to evaluate the usefulness of measurements by bioelectrical impedance analysis (BIA) for these characterizations.

Methods: Investigation pre-and post-hemodialysis of (A) the state of nutrition by body mass index (BMI), serum albumin and pre-albumin, and BIA-derived estimates of the fraction body fat over body weight (BF/W) and phase angle, and (B) the state of hydration by clinical examination for volume excess and BIA-derived estimates of body water (V), extracellular volume (ECFV), and the fractions ECFV/V and V over fat-free mass (V/FFM) in 10 patients on chronic hemodialysis at JUTH.

Results: (A) Nutritional estimates post-dialysis: BMI 22.3±2.9 kg/m^2, with 5 values in the normal range (20-25 kg/m^2), 4 values < 20 kg/m^2 and 1 value > 27.5 kg/m^2; serum albumin 29.8±6.8 g/L, with 1 value in the normal range (35-50 g/L) and 9 values < 35 g/L; serum pre-albumin 0.26±0.12 g/L, with 6 values in the normal range (0.18-0.45 g/L) and 4 values < 0.18 g/L); BF/W 0.19±0.08, with 5 values in the normal range, 4 values indicating fat deficit and 1 value indicating fat excess; phase angle 4.4±0.8 degrees, with 5 values in the normal range (5-8 degrees) and 5 values indicating malnutrition (< 4 degrees). There was strong concordance between hypoalbuminemia, low serum pre-albumin and low values of BF/W and phase angle. Pre- and post-dialysis values agreed closely. (B) Post-dialysis estimates of hydration by BIA: V 38.6±9.8 L; ECFV 18.8±6.6 L; ECFV/V 0.48±0.06; V/FFM 0.73±0.04. The change in V during dialysis (-0.7±3.3 L) correlated highly (r = 0.99) with the corresponding change in body weight (-0.8±3.3 kg). The fractions V/FFM and ECFV/V were higher in patients with clinical evidence of volume overload than those with post-dialysis euvolemia. BIA appeared to underestimate the excess body water in a patient with ascites and pleural effusions.

Conclusions: With the exception of patients with large fluid collections in body cavities, BIA provides reliable estimates of nutrition and hydration in Nigerian patients on chronic

Abbreviated title: Nutrition and hydration in hemodialysis

Abstract

Background: Nutrition and hydration of the dialysis patients have major influences on the outcomes of chronic hemodialysis.

Purpose: To characterize the states of nutrition and hydration in patients on chronic hemodialysis at Jos University Teaching Hospital (JUTH) and to evaluate the usefulness of measurements by bioelectrical impedance analysis (BIA) for these characterizations.

Methods: Investigation pre-and post-hemodialysis of (A) the state of nutrition by body mass index (BMI), serum albumin and pre-albumin, and BIA-derived estimates of the fraction body fat over body weight (BF/W) and phase angle, and (B) the state of hydration by clinical examination for volume excess and BIA-derived estimates of body water (V), extracellular volume (ECFV), and the fractions ECFV/V and V over fat-free mass (V/FFM) in 10 patients on chronic hemodialysis at JUTH.

Results: (A) Nutritional estimates post-dialysis: BMI 22.3±2.9 kg/m^2, with 5 values in the normal range (20-25 kg/m^2), 4 values < 20 kg/m^2 and 1 value > 27.5 kg/m^2; serum albumin 29.8±6.8 g/L, with 1 value in the normal range (35-50 g/L) and 9 values < 35 g/L; serum pre-albumin 0.26±0.12 g/L, with 6 values in the normal range (0.18-0.45 g/L) and 4 values < 0.18 g/L); BF/W 0.19±0.08, with 5 values in the normal range, 4 values indicating fat deficit and 1 value indicating fat excess; phase angle 4.4±0.8 degrees, with 5 values in the normal range (5-8 degrees) and 5 values indicating malnutrition (< 4 degrees). There was strong concordance between hypoalbuminemia, low serum pre-albumin and low values of BF/W and phase angle. Pre-and post-dialysis values agreed closely. (B) Post-dialysis estimates of hydration by BIA: V 38.6±9.8 L; ECFV 18.8±6.6 L; ECFV/V 0.48±0.06; V/FFM 0.73±0.04. The change in V during dialysis (-0.7±3.3 L) correlated highly (r = 0.99) with the corresponding change in body weight (-0.8±3.3 kg). The fractions V/FFM and ECFV/V were higher in patients with clinical evidence of volume overload than those with post-dialysis euvolemia. BIA appeared to underestimate the excess body water in a patient with ascites and pleural effusions.

Conclusions: With the exception of patients with large fluid collections in body cavities, BIA provides reliable estimates of nutrition and hydration in Nigerian patients on chronic hemodialysis. Both malnutrition and overhydration are common in JUTH patients on chronic hemodialysis. These findings may assist in designing preventive and therapeutic interventions for these patients.

Key Words: Hemodialysis, nutrition, hydration, bioimpedance, Nigeria

Introduction

The number of patients reaching end-stage renal disease (ESRD) is increasing globally. In tertiary care centers in Nigeria, renal failure accounts for 8% of the total hospital admissions[1,2]. In the medical wards of the Jos University Teaching Hospital (JUTH), renal failure was found to be the sixth leading cause of death after AIDS-related disease, chronic liver disease, neoplasms, cardiovascular disease, and the non-ESRD complications of diabetes mellitus[3].

Chronic dialysis prevents death from uremia, but is associated with high rates of mortality from other causes. Proper nutrition[4,5] and prevention of overhydration[6] are critical for the survival of patients on chronic dialysis. In this study, we evaluated the nutritional and hydration status of patients on chronic dialysis at JUTH by bioelectrical impedance analysis (BIA), a simple bedside procedure which has been used to evaluate the state of nutrition[7-14] and hydration[15-19] in patients on chronic dialysis. We compared the findings of BIA to clinical estimates and pertinent laboratory values. The purposes of the study were to characterize the usefulness and limitations of BIA in assessing nutrition and hydration of patients on chronic dialysis, and to identify potentially correctable deficits in the procedures used in the dialysis of ESRD patients in Nigeria.

Materials and methods

Subjects and procedures

We recruited into the study 10 patients who received chronic hemodialysis at the dialysis unit in JUTH between June 15, 2003 and August 15, 2003. Six patients were studied once while four patients were studied twice with an interval of 10 to 30 days between the two studies. The protocol of the studies and the informed consent forms had been approved by the Institutional Review Boards of the Faculty of Medical Sciences at Jos University and the University of New Mexico School of Medicine. During interviews conducted prior to a dialysis session, the patients were informed about the purpose and methods of the study. All interviewed patients indicated that they understood the study and provided signed informed consent.

After signing the informed consent form, the patients had their height and weight measured by an experienced dialysis nurse and a member of the research team. They then had their body composition evaluated by single-frequency BIA using a BIA-Quantum impedance analyzer (RJL Inc, Clinton Township, Mich.). The instrument delivers an alternating 800 μA current at a frequency of 50 kHz. Impedance measurements were made as the patients lay in the supine position on a nonconducting surface with limbs abducted approximately 30 from the body. Signal introducing electrodes were placed on the first joint of the middle finger and just below the middle toe. The detecting electrodes were placed with the upper edge of the electrode bisecting the ulnar head of the wrist and the median malleolus of the foot. Care was taken that the signal and detecting electrodes were not closer than 5 cm. Duplicate measurements of impedance were made in each subject[20-26]. The BIA procedure is brief and without discomfort or danger. The electrical current is not perceived by the subjects studied.

After the BIA procedure, a 20 mL sample of blood was obtained pre-dialysis and the dialysis session was started. A 10 mL blood sample was obtained immediately post-dialysis. Both blood samples were obtained from the arterial dialysis blood line. Post-dialysis body weight was measured by the same personnel measuring the pre-dialysis weight and on the same scale. The patients did not consume food during dialysis. Consequently, the weight change during a dialysis session reflected body fluid changes. Approximately 10 minutes after the end of the dialysis session, the patients had a repeated evaluation of body composition by BIA.

Estimates of nutrition

Body mass index (BMI), and serum albumin and pre-albumin were the nutritional parameters that were compared to the parameters derived from BIA. The normal range for BMI is 20-25 kg/m^2. BMI values > 27.5 kg/m^2 indicate obesity. BMI values < 20 kg/m^2 indicate weight deficit. Low BMI, an index of poor nutrition, predicts high mortality in ESRD patients (27). Weight deficit is found in 40% of the JUTH patients approaching ESRD (28).

Serum albumin was measured by the bromcresol green method. The normal range for serum albumin values by this method is 35-50 g/L. Serum albumin values < 30 g/L indicate severe hypoalbuminemia. Serum pre-albumin was determined by turbimetric measurement of antigen-antibody complexes using an antibody to pre-albumin. The normal range for pre-albumin is 0.18-0.45 g/L.

In BIA studies, impedance (Z) is the vector sum of resistance (R) and reactance (Xc), which are the two measurements directly reported by the BIA instrument. Resistance is the opposition to an electrical current. In cylindrical wires conducting electrical current, resistance is determined by the material of the wire plus the length and diameter of the cylinder. BIA measurements are based on the assumption that the human body is made up of a series of serially connected cylinders (arms, legs, trunk) with known length and diameter. In this case, the only unknown determinant of resistance is the composition of the fluids in these cylinders. Reactance reflects the portion of impedance due to the presence of capacitive elements, such as cell membranes[9].

R and Xc from each BIA measurement are entered in a computer software program along with demographic information (gender) and anthropometric measurement (weight and

height) of the subject. The software programs contain equations that derive from the variables entered as parameters of body composition, nutrition and hydration. Body weight (W) consists of body fat (BF) and fat-free mass (FFM). The BIA parameters that are related to nutrition include BF_{BIA}, FFM_{BIA} and phase angle, which is the tangent of the ratio Xc/R. The normal range for body fat content (BF/W) is 0.12-0.20 in males and 0.20-0.30 in females. BF/W values > 0.20 in males and > 0.30 in females indicate excess body fat. BF/W values < 0.12 in males and < 0.20 in females indicate fat deficit[29]. Fat deficit detected by BF_{BIA} is an important indicator of poor nutrition in patients on chronic dialysis[7]. Phase angle has emerged as another nutrition index for patients on chronic dialysis with important prognostic value[30]. The normal range for phase angle is 5-8 degrees. Phase angle values < 4 degrees predict high mortality in patients on chronic dialysis[30].

A second set of estimates of BF/W was obtained using the Gallagher formula ($BF_{Gallagher}$/W) for Caucasians and African Americans[31]:

$$(BF_{Gallagher}/W)100 = 64.5 848/BMI + 0.079Age 16.4Gender + 0.05GenderAge + 39Gender/BMI \quad \{1\}$$

where BMI is the post-dialysis BMI in kg/m^2, age is in years, male gender is assigned the value one and female gender is assigned the value zero. $FFM_{Gallagher}$ was calculated as W - $BF_{Gallagher}$.

Estimates of hydration

BIA measurements permit one to estimate total body water (V), extracellular volume (ECFV) and intracellular volume (ICFV). Patients with renal failure usually have ECFV excess and may also have ICFV abnormalities. A hemodialysis session could potentially affect both ICFV and ECFV. Fluid shifts between the intracellular and extracellular compartments (internal shifts) are manifested by changes in serum sodium concentration. If the initial (pre-dialysis) ICFV ($ICFV_1$) is known, and $[Na]_1$ and $[Na]_2$ are respectively the initial (pre-dialysis) and final (post-dialysis) serum sodium concentrations, the amount of fluid shifted internally (V_{Int}) is calculated as:

$$V_{int} = ICFV_1([Na]_1/[Na]_2-1) \quad \{2\}$$

In equation 2, a decrease in [Na] ($[Na]_1 > [Na]_2$) signals ICFV gain through transfer of fluid into the intracellular compartment, while an increase in [Na] ($[Na]_1 < [Na]_2$) indicates loss of ICFV through fluid transfer outside the intracellular compartment. Since they provide estimates of the ICFV, BIA measurements allow one to calculate the amount of fluid transferred between the ICFV and the ECFV. The change in ECFV secondary to the loss or gain of ICFV is equal to the change in ICFV, but with an opposite sign.

In healthy individuals, extracellular volume varies with body size, gender, age, body fat, ethnicity, chronic illness and probably other factors including diet. To detect differences between genders, ethnic groups, or other groups of subjects, it is customary to normalize ECFV to parameters of body size, such as weight or height. To detect abnormalities in ECFV in this study, we normalized ECFV to total body water, which is affected by the same factors as ECFV. One BIA study reported a correlation of 0.8 between ECFV and V in normal subjects[32]. Despite this high degree of correlation, the relationship ECFV/V varies considerably between different groups of subjects without hydration abnormalities. For example, the development of obesity causes disproportionately larger increases in ECFV than in V[33]. Largely because of its variation in subjects without hydration abnormalities, the normal range of the ratio ECFV/V has not been clearly defined. From BIA measurements, the mean ECFV/V values vary between 0.40 and 0.45, while the range of the normal ECFV/V values could be between 0.35 and 0.50[32,34,36].

Another way to characterize the state of hydration is by the use of the V/FFM ratio. This approach is based on the following facts: (a) in the body, water is distributed only in FFM (not in BF); and (b) in both animals and

humans with normal body water, the V/FFM ratio is constant at approximately 0.72 with a very narrow range of the normal values[37,38]. FFM at normal hydration is called the edema-free, fat-free body mass.

In this study, we considered the range V/FFM as the "gold standard" of hydration assessment precisely because of the narrow range of the normal values. We considered V/FFM values > 0.74 as indicating water excess. We used the intradialytic changes in serum sodium concentration and the ratios ECFV/V and V/FFM to characterize the status of V, ICFV and ECFV. Purely isotonic changes in ECFV (isotonic external fluid shifts) affect the ratios V/FFM and ECFV/V, but not [Na], while internal fluid shifts between the two major body fluid compartments affect [Na] and the ratio ECFV/V, but not the ratio V/FFM. Measurement before and after a dialysis session of the serum sodium concentration and BIA hydration parameters (V, FFM, ICFV, ECFV) allow quantitative assessment of body fluid changes during dialysis.

In addition to V_{BIA}, a second estimate of body water was obtained from the Gallagher formula assuming normal body water content, as follows:

$$V_{Gallagher} = 0.72 FFM_{Gallagher} \quad \{3\}$$

Statistics and other comparisons

Continuous variables are presented as mean ± standard deviation. Statistical methods of comparison used included the two-tailed paired t test, the two-tailed Student's t test, correlation, and the Bland-Altman statistic of limits of agreement (d ± 2ds) where d is the mean difference between estimates of the same variable by two different methods and ds is the standard deviation of this mean difference[39].

Qualitatively, we tested whether the BIA measurements of body water recorded accurately the direction of the change in body water content (the ratio V/W) during a dialysis session. When there is net fluid loss the ratio V/W mathematically decreases from the pre-dialysis to the post-dialysis state, whereas when there is net fluid gain during a dialysis session the ratio V/W increases[40].

In one unique patient who had progressive weight gain due to fluid retention from a known "dry" weight status, we compared the BIA estimates of nutrition and hydration to estimates obtained from a method of

Table 1. Patient characteristics

Patient	Gender (M, F)	Age years	Height m	Weight * kg	Dialysis duration months
1	M	44	1.74	64.2	4
2	F	58	1.74	85.3	5
3	M	36	1.74	71.0#	9
4	M	53	1.73	59.6	108
5	F	22	1.64	55.7	38
6	F	47	1.57	49.1	3
7	M	42	1.88	81.5	1
8	M	53	1.57	60.2	1
9	F	20	1.56	58.7	3
10	M	60	1.60	46.0	13
Mean		43.6	1.68	63.1	18.5
SD		6.6	0.11	7.9	33.3

* Post-dialysis after the first study. # Stable post-dialysis weight for at least one month obtained four months prior to the BIA study. In the ensuing three months, patient 3 had progressive weight gain secondary to the development of massive ascites, bilateral pleural effusions and anasarca. On the day of the BIA study, his post-dialysis weight was 104 kg. SD = standard deviation.

Table 2. Nutrition indices, first study post dialysis

	Mean SD	Normal values N (Percent)	Low values N (Percent)	High values N (Percent)
Body mass index (kg/m^2)	22.3 2.9	5 (50)	4 (40)	1 (10)
Serum albumin (g/L)	29.8 6.8	1 (10)	9 (90)	0
Serum pre-albumin (g/L)	0.26 0.12	6 (60)	4 (40)	0
BF_{BIA}/W (kg/kg)	0.19 0.11	5 (50)	4 (40)	1 (10)
$BF_{Gallagher}/W$ (kg/kg)	0.22 0.08	7 (70)	1 (10)	2 (20)
Phase angle (degrees)	4.4 0.8	5 (50)	5 (50)	0

SD = standard deviation; BF = body fat; W = weight; BIA = bioelectrical impedance; Gallagher = Gallagher formula. Pre- and post-dialysis values agreed closely

Table 3. Hydration indices, first study

Variable	Pre-dialysis	Post-dialysis	p-Value
V_{BIA} (L)	39.4 10.4	38.6 9.8	<0.05
$V_{Gallagher}$ (L)	34.7 6.8	34.4 6.7	<0.05
$ICFV_{BIA}$ (L)	19.1 5.7	20.6 5.9	<0.05
$ECFV_{BIA}$ (L)	20.3 6.2	18.8 6.6	<0.05
$ECFV/V_{BIA}$ (L/L)	0.50 0.09	0.48 0.06	<0.05
V/FFM_{BIA} (L/kg)	0.73 0.04	0.73 0.04	NS

V = body water; BIA = by bioimpedance; Gallagher = from the Gallagher formula; ECFV = extracellular volume; ICFV = intracellular volume; FFM = fat free mass. The values are presented as mean standard deviation.

Table 4. Estimates by the Gallagher formula and by BIA in a patient with fluid gain

Parameter	Gallagher formula[1]	Gallagher formula[2]	BIA
BF, kg	13.0	13.0	17.1
FFM, kg	58.0[3]	58.0[3]	86.8
V, L	41.8	74.8	67.1
V/FFM, L/kg	0.72[4]	1.29[4]	0.77
ICFV, L	25.1[5]	25.1[5]	31.0
ECFV, L	16.7[6]	49.7[7]	36.1
ECFV/V, L/L	0.40	0.66	0.54
V/W, L/L	0.59	0.72	0.65

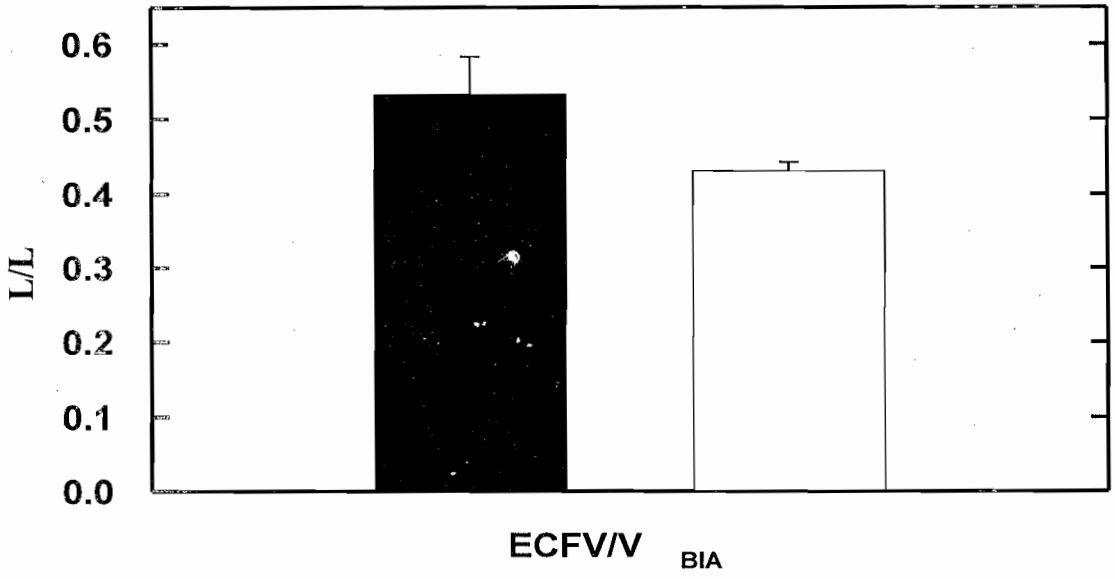
BF = body fat; FFM = fat-free mass; V = body water, ICFV = intracellular volume; ECFV = extracellular volume; W = body weight

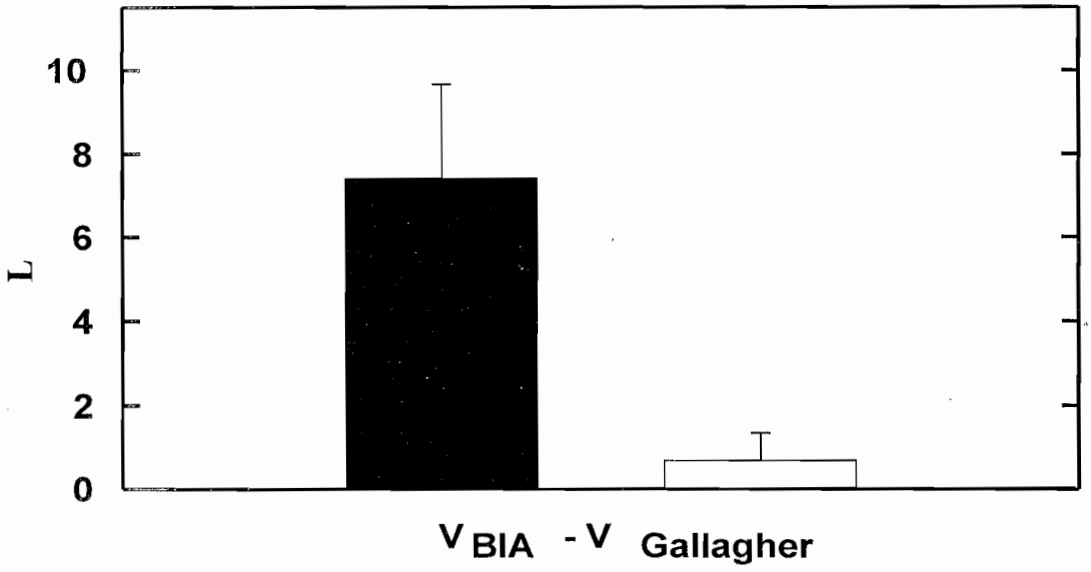
[1] Calculation of body composition at a "dry" body weight of 71 kg; [2] V and ECFV estimates obtained by adding the difference between actual and dry weight (104 - 71 = 33 L) to dry weight (71 kg) Gallagher estimates of V and ECFV, respectively; [3] The so-called edema-free, fat-free mass; [4] The ratio of body water over edema-free, fat-free mass; [5] 0.6(body water obtained from the Gallagher formula at 71 kg of weight); [6] 0.4(body water obtained by the Gallagher formula at 71 kg of weight) [7] (Dry weight value obtained from the Gallagher formula) +33 L.

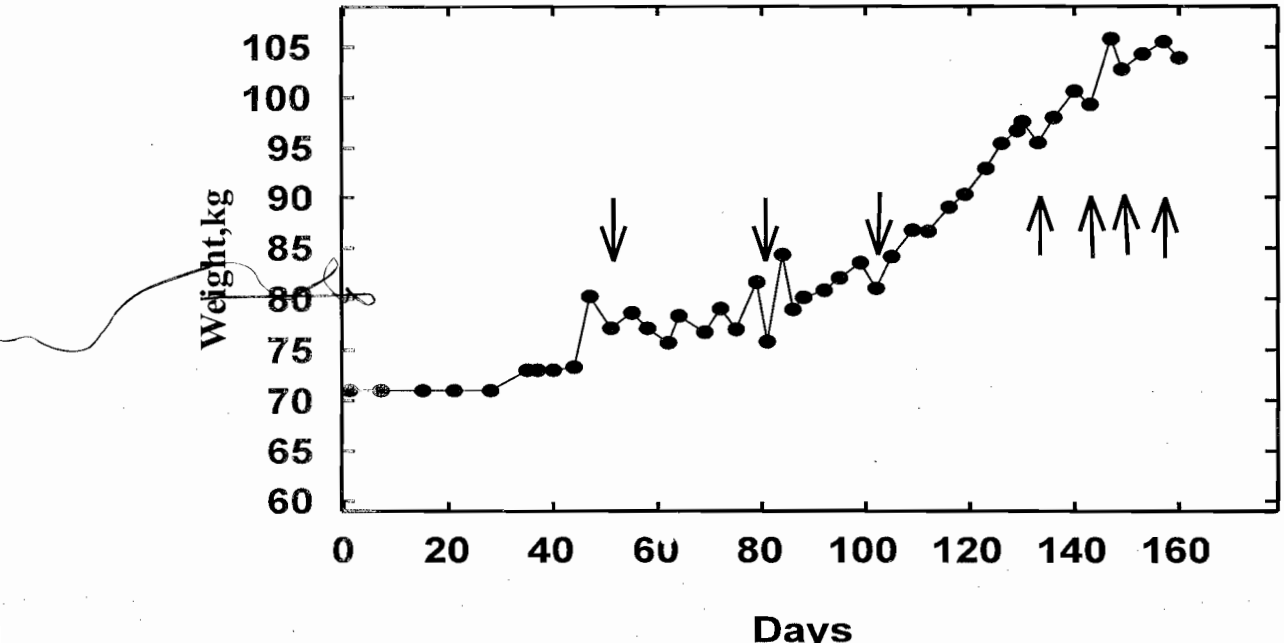
LEGENDS

Figure 1. Comparison of the post-dialysis values $ECFV/V_{BIA}$ (upper panel) and V_{BIA} $V_{Gallagher}$ (lower panel) between five patients with excess body water by BIA ($V/FFM_{BIA} > 0.74$, dark bars) and five patients without excess body water (V/FFM_{BIA} 0.74, open bars) in the first study. Differences were significant at $p < 0.001$.

Figure 2. Evolution of post-dialysis weight in a JUTH patient on chronic hemodialysis with progressive development of massive ascites, bilateral pleural effusions and anasarca. Arrows: progress height gain post dialysis.


0.6
0.5
0.4
0.3
0.2
0.1
0.0
L/L
ECFV/V BIA


10
8
6
4
2
0
L
V BIA - V Gallagher


105
100
95
90
85
80
75
70
65
60
Weight,kg
0
20
40
60
80
100
120
140
160
Days

Discussion

This study documented the frequency and magnitude of nutrition and hydration abnormalities in patients on chronic hemodialysis at JUTH and illustrated some of the limitations of BIA as a method for analyzing hydration. Malnutrition is common in dialysis populations and has dire consequences[42-44]. This potentially preventable condition has a higher prevalence in JUTH patients with pre-ESRD stages of chronic kidney disease (CKD) than in normal controls from the same population[28]. Consequently, early diagnosis of CKD with timely intervention (nutritional assistance, management of associated catabolic conditions, timely initiation of dialysis and adequate dialysis) is the best way to combat malnutrition in these patients.

Two of the indices estimated from BIA, body-fat content and phase angle, are considered as indices of nutrition in patients on dialysis[7]. These BIA indices correlated closely with the serum indices of nutrition. This finding raises the question whether BIA evaluation of nutritional status is redundant in patients on chronic dialysis. However, BIA has certain advantages including the detection of body-fat deficit, which may not be detected by formulas based on BMI because of excess body water (see below), and the calculation of the phase angle, which is a strong predictor of outcomes in patients on chronic dialysis[30]. In addition, low serum albumin may reflect not nutritional status, but inflammatory state in a large percent of patients on chronic dialysis[45], while serum pre-albumin is not measured routinely.

The role of BIA in assessing hydration of dialysis patients appears to be even more important than its role in assessing their nutritional status. Clinical estimates of hydration, although indispensable, can be misleading, especially when subtle abnormalities are present, which nevertheless have clinical implications in dialysis patients[6]. In this study, BIA estimates of hydration were compared to estimates obtained using the Gallagher formula.

The Gallagher formula was derived by comparing BMI to estimates of body composition obtained in healthy subjects by a reference method[28]. A comparable formula for assessing body composition in Nigerians is not available and should be developed. The two most important sources of systematic error associated with any formula predicting body composition from BMI are hydration abnormalities and deviations of body fat from the fat content expected for a given BMI[46]. Patients on chronic dialysis frequently develop both fat deficits and fluid excesses. BIA can detect hydration abnormalities not detectable by anthropometric formulas including formulas based on BMI[47-49]. We showed that the differences between the estimates of body water by BIA and by the Gallagher formula were related to the hydration status of the patients (Fig. 1). BIA estimates of hydration agreed with the clinical presence or absence of edema and with the known intradialytic change in body water. Thus BIA estimates of hydration have a clear advantage over estimates obtained from anthropometry in patients on dialysis.

Our study also illustrated certain limitations of BIA in estimating hydration. The direction of the intradialytic change in body water content estimated by BIA was erroneous in three of the ten patients. This finding may be due to the relatively small changes in body water during dialysis in two patients. The last patient in this group was the patient who had the massive fluid gain. BIA clearly underestimated body water and extracellular volume in this patient. The differences in these volumes shown in Table 4 likely represent underestimates of the actual differences because we assumed that body composition (body fat, edema-free fat-free mass) did not change over the months of fluid gain. However, the patient reported continuous anorexia and frequent vomiting during this period and may well have lost body fat. BIA appears to underestimate fluid excesses when there are large collections of fluid in central body cavities.

In conclusion, BIA is very useful in documenting hydration abnormalities in patients on chronic dialysis, while its use in documenting nutritional deficits is tempered by the fact that certain biochemical parameters, particularly serum albumin, which is routinely measured, have a sensitivity

in detecting poor nutrition similar to or greater than that of BIA. Both poor nutrition and overhydration are prevalent in JUTH patients on chronic dialysis. Prevention of malnutrition in these patients should start in the early stages of CKD. An effort to prevent overhydration by aggressive ultrafiltration during dialysis is warranted. Use of repeated BIA measurements to achieve normal hydration would be desirable. In its absence, continuous evaluation for correction of edema and hypertension is the indicated clinical practice.

Acknowledgment

This study was supported by a grant from the Minority International Research Training (MIRT) program from the Fogarty International Center of the National Institute of Health (NIH), Bethesda, Maryland.

References

1. Akinsola W, Odesamni WO, Ogunniyi JO, Ladipo GOA. Diseases causing renal failure in Nigerians a prospective study of 100 cases. Afr J Med Sci 1989; 18: 131-135.
2. Agaba EI, Agbaji OO, Anteyi EA. Pattern of renal diseases in North Central Nigeria. J Med Trop 2002; 4: 33-37.
3. Mandong BM, Madaki AJK. Mortality in a Nigerian teaching hospital. Experience at Jos University Teaching Hospital (JUTH). Highlands Med Res J 2002; 1: 16-18.
4. Lowrie EG, Lew NL. Death risk in hemodialysis patients: The predictive value of commonly measured variables and an evaluation of death rate differences between facilities. Am J Kidney Dis 1990; 15: 458-482.
5. Leavey SF, Strawderman RL, Jones CA, Port FK, Held PS. Simple nutritional indicators as independent predictors of mortality in hemodialysis patients. Am J Clin Nutr 1998; 31: 997-1006.
6. Charra B, Calemard E, Ruffet M, Chazot C, Terrat J, Vanel T, Laurent G. Survival as an index of adequacy of dialysis. Kidney Int 1992; 41: 1286-1291.
7. Dumler F, Schmidt R, Kilates C, Faber M, Lubkowski T, Frinak S. Use of bioelectrical impedance for the nutritional assessment of chronic hemodialysis patients. Miner Electrol Metab 1992; 18: 284-287.
8. Schmidt R, Dumler F, Kruz C, Lubkowski T, Kilates C. Improved nutritional follow-up of peritoneal dialysis patients with bioelectrical impedance. Adv Perit Dial 1992; 8: 157-159.
9. Chertow GM, Lowrie EG, Wilmore DW, Gonzalez J, Lew NL, Ling J, Leboff MS, Gottlieb MN, Huang W, Zebrowski B, College J, Lazarus JM. Nutritional assessment with bioelectrical impedance analysis in maintenance hemodialysis patients. J Am Soc Nephrol 1995; 6: 75-81.
10. Maggiore Q, Nigrelli S, Ciccarelli C, Grimaldi C, Rossi GA, Michelassi C. Nutritional and prognostic correlates of bioimpedance indexes in hemodialysis patients. Kidney Int 1996; 50: 2103-2108.
11. Passadakis P, Sud K, Dutta A, Singhal M, Pettit J, Chatallalsingh C, Thodis E, Vargemezis V, Oreopoulos D. Bioelectrical impedance analysis in the evaluation of the nutritional status of continuous ambulatory peritoneal dialysis patients. Adv Perit Dial 1999; 15: 147-152.
12. Fein PA, Gundumalla G, Jorden A, Matza B, Chattopadhyay J, Avram MM. Usefulness of bioelectrical impedance analysis in monitoring nutrition status and survival of peritoneal dialysis patients. Adv Perit Dial 2002; 18: 194-199.
13. Dumler F, Kilates C. Body composition analysis by bioelectrical impedance in chronic maintenance dialysis patients: Comparisons to the National Health and Nutrition Examination Survey III. J Ren Nutr 2003; 13: 166-172.
14. Mushnick, Fein PA, Mittman N, Goel N, Chattopadhyay J, Avram MM. Relationship of bioelectrical impedance parameters to nutrition and survival in peritoneal dialysis patients. Kidney Int 2003; 64, Suppl. 87: S53-S56.
15. Bohm D, Odaischi M, Beyerlein C, Overbeck W. Total body water: Changes during dialysis estimated by

bioimpedance analysis. Infusiontherapie 1990; 17, Suppl. 3: 75-78.
16. Kurtin PS, Shapiro AC, Tomita H, Raizman D. Volume status and body composition of chronic dialysis patients: Utility of bioelectrical impedance plethysmography. Am J Nephrol 1990; 10: 363-367.
17. Kouw PM, Olthof CG, ter Wee PM, Oe LP, Donker AJ, Schneider H, de Vries PM. Assessment of post dialysis dry weight: An application of the conductivity measurement method. Kidney Int 1992; 41: 440-444.
18. Pastan S, Gassensmith C. Total body water measured by bioelectrical impedance in patients after hemodialysis: Comparison with urea kinetics. Am Soc Artif Internal Organs J 1992; 38: M186-M189.
19. Ho LT, Kushner RF, Schoeller DA, Kudivaka R, Spiegel DM. Bioimpedance analysis of total body water in hemodialysis patients. Kidney Int 1994; 46: 148-1442.
20. VanderJagt DJ, Okolo SN, Rabasa AI, Glew RH. Bioelectrical impedance analysis of the body composition of Nigerian children with sickle cell disease. J Trop Pediatr 2000; 46: 67-72.
21. VanderJagt DJ, Morales M, Thacher TD, Diaz M, Glew RH. Bioelectrical impedance analysis of the body composition of Nigerian children with calcium-deficiency rickets. J Trop Pediatr 2001; 47: 92-97.
22. VanderJagt DJ, Harmatz P, Scott-Emuakpor AB, Vichinsky E, Glew RH. Bioelectrical impedance analysis of the body composition of children and adolescents with sickle cell disease. J Pediatr 2002; 140: 681-687.
23. Glew RH, Kassam HA, Bhanji RA, Okorodudu A, VanderJagt DJ. Serum lipid profiles and risk of cardiovascular disease in three different male populations in Northern Nigeria. J Health Popul Nutr 2002; 20: 166-174.
24. Glew RH, Conn CA, Bhanji R, Calderon P, Barnes C, VanderJagt DJ: Survey of growth characteristics and body composition of Fulani children in a rural hamlet in Northern Nigeria. J Trop Pediatr 2003; 49: 313-322.
25. Glew RH, Brock HS, VanderVoort J, Agaba P, Harkins MS, VanderJagt DJ: Lung function and nutritional status of semi-nomadic Fulani children and adolescents in Northern Nigeria. J Trop Pediatr 2004; 50: 20-25.
26. Glew RH, Bhanji A, VanderJagt DJ: Effects of displacement resulting from ethnic/religious conflicts on the growth and body composition of Fulani children in Northern Nigeria. J Trop Pediatr 49:279-285, 2003.
27. Kalantar-Zadech K, Bloch G, Humphreys MH, Kopple JD. Reverse epidemiology of cardiovascular risk factors in maintenance dialysis patients. Kidney Int 2003; 63: 793-808.
28. Agaba EI, Agaba PA. Prevalence of malnutrition in Nigerians with chronic renal failure. Int Urol Nephrol 2003; 36: 89-93.
29. Bray GA, Bouchard C, James WPT. Definitions and proposed current classification of obesity. In: Bray GA, Bouchard C, James WPT, eds. Handbook of Obesity, 1st edition. New York, NY, USA, Marcel Dekker 1998: pp 31-40.
30. Chertow GM, Jacobs DO, Lazarus JM, Lew NL, Lowrie EG. Phase angle predicts survival in hemodialysis patients. J Ren Nutr 1997; 7: 204-207.
31. Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percent body fat ranges: An approach for developing guidelines based upon body mass index. Am J Clin Nutr 2000; 72: 694-701.
32. Segal KR, Burastero S, Chun A, Coronel P, Pierson RN, Wang J. Estimation of extracellular and total body water by multiple-frequency bioelectrical impedance measurements. An J Clin Nutr 1991; 54: 26-29
33. Moore FD, Olesen KH, McMurrey JD, Parker HV, Ball MR, Boyden C. The Body Cell Mass and its Supporting Environment in Body Composition in Health and Disease. Philadelphia, PA, USA, WB Saunders, 1963: 240-308.

34. Ducrot H, Thomasset A, Jolly R, Eyraud C, Lenoir J. Determination du volume des liquids extracellulaires chez l'homme par la mesure de l'impedance corporelle totale. Presse Med 1970; 78: 2269-2272.
35. Jenin P, Lenoir J, Roullet C, Thomasset AL, Ducrot H. Determination of body fluid compartments by electrical impedance measurements. Aviat Space Environ Med 1975; 46: 152-155.
36. Lukaski H, Bolonchuk W. Estimation of body fluid volumes using tetrapolar bioelectrical impedance measurements. Aviat Space Environ Med 1988; 59: 1163-1169.
37. Wang Z, Deuremberg P, Wang W, Pietrobelli A, Baumgartner RN, Heymsfield SB.
Hydration of fat-free mass: New physiological modeling approach. Am J Physiol 1999; 276: E995-E1003.
38. Wang Z, Deuremberg P, Wang W, Pietrobelli A, Baumgartner RN, Heymsfield SB.
Hydration of fat-free mass: Review and critique of a basic body composition constant. Am J Clin Nutr 1999; 69: 833-841.
39. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986; i: 307-310.
40. Tzamaloukas AH. Effect of edema on urea kinetic studies in peritoneal dialysis. Perit Dial Int 1994; 14: 398-401.
41. Tzamaloukas AH, Murata GH, Dimitriadis A, Voudiklari S, Antoniou S, Malhotra D, Kakavas J, Dombros NV, Nicolopoulou N, Balaskas EV. Fractional urea clearance in continuous peritoneal dialysis: Effects of volume disturbances. Nephron 1996; 74: 567-571.
42. Acciardo SR, Moore LW, Latour PA. Malnutrition as the main factor for morbidity and mortality of dialysis patients. Kidney Int 1983; 24: S199-S203.
43. Kopple JD. Effect of nutrition on morbidity and mortality in maintenance dialysis patients. Am J Kidney Dis 1994; 24: 1002-1004.
44. Bergstrom JD. Nutrition and mortality in hemodialysis. J Am Soc Nephrol 1995; 6: 1329-1341.
45. Malhotra D, Murata GH, Tzamaloukas AH. Serum albumin in peritoneal dialysis: Clinical significance and important influences on its levels. Int J Artif Organs 1997; 20: 251-254.
46. Tzamaloukas AH, Murata GH, VanderJagt DJ. Limitations and pitfalls of body mass index as an indicator of body fat content. In: Focus on Body Mass Index and Health Research, LA Ferrera, ed. Nova Science Publishers, Inc., Hauppage, NY, 2005: 59-80.
47. Tzamaloukas AH, Murata GH, VanderJagt DJ, Glew RH. Estimates of body water, fat-free mass, and body fat in patients on peritoneal dialysis by anthropometric formulas. Kidney Int 2003; 63: 1605-1617.
48. Piccoli A, for the Italian CAPD-BIA Study Group: Bioelectric impedance vector distribution in peritoneal dialysis patients with different hydration status. Kidney Int 65: 1050-1063, 2004.
49. Di Iorio BR, Scalfi L, Terraciano V, Bellizi V. A systematic evaluation of bioelectrical impedance measurements after hemodialysis session. Kidney Int 2004; 65: 2435-2440.