International Journal of Obesity (2001) 25, 265–272
 0307–0565/01 $15.00
www.nature.com/ijo

PAPER

Abnormalities of bioimpedance measures in overweight and obese hemodialyzed patients

B Guida[1]*, L De Nicola[2], P Pecoraro[1], R Trio[1], F Di Paola[1], C Iodice[2], V Bellizzi[3] and B Memoli[4]

[1]*Department of Neuroscience/Physiology Nutrition Section, University Federico II, Naples, Italy;* [2]*Second University of Naples, Naples, Italy;* [3]*Lauria Hospital, Naples, Italy; and* [4]*Division of Nephrology, University Federico II, Naples, Italy*

BACKGROUND: The body composition in overweight and obese hemodialyzed patients (HD) remains ill-defined. This study evaluates in HD patients the influence of body size, as indicated by body mass index (BMI, kg/m^2), on body composition by measuring bioimpedance analysis (BIA)-derived variables (phase angle (PA), fat-free mass (FFM) and body cell mass (BCM).
METHODS: We studied 50 Caucasian patients (mean age 62.8 ± 9.2 y) on standard bicarbonate hemodialysis for at least 12 months who regularly achieved dry weight in post-HD, received similar dialysis doses and were free from inflammation/infection. Thirty-eight gender- and age-matched healthy subjects were included as controls (CON). Both HD and CON were divided into three groups on the basis of their BMI(kg/m^2) 18.5 – 24.9, normal-weight (NW); 25 – 29.9, overweight (OW); and ≥30, obese (OB). In HD patients, BIA was performed 30 min after the end of dialysis.
RESULTS: Seven patients were obese (12%) while 16 were overweight (32%); in CON, 12 were obese (31%) and 12 overweight (31%). BIA-measured extracellular water was comparable in all groups. PA, which was similar in normal-weight HD and CON (6.2 ± 0.9° and 6.3 ± 0.8°), decreased in OW- and OB-HD patients (5.3 ± 1.0° and 5.2 ± 0.6°, respectively; $P < 0.05$ *vs* NW-HD) while it was unchanged in OW- and OB-CON (6.1 ± 0.8° and 5.9 ± 0.5°, $P < 0.05$ *vs* respective HD groups). In OW and OB patients, the lower PA values were coupled with a major reduction of BIA-derived percentage BCM and FFM ($P < 0.05$ *vs* NW-HD, and *vs* OW- and OB-CON). In patients, PA and BCM correlated with anthropometry-measured FFM. Of note, serum albumin and protein catabolic rate were significantly reduced in OB patients.
CONCLUSION: In overweight and obese HD patients, BIA-derived FFM, BCM and PA are significantly lower with respect to normal-weight patients and BMI-matched controls. These abnormalities of body composition are coupled with reduction of anthropometric measures of lean mass and a decrease of protein intake that, however, becomes significant only in the obese. We therefore suggest that overweight and obese HD patients are at risk of protein malnutrition in spite of excessive energy intake. BIA may be considered as a useful diagnostic tool to detect such a condition early.
International Journal of Obesity (2001) **25,** *265 – 272*

Keywords: hemodialysis; obesity; bioelectrical impedance analysis; anthropometry

Introduction

In uremic patients undergoing maintenance hemodialysis (HD), protein-energy malnutrition is a frequent clinical feature, with the prevalence of this phenomenon averaging 20 – 40%.[1,2] The presence of protein-energy malnutrition is a powerful risk factor for morbidity and mortality in these patients.[1,24–6] Therefore, the periodic assessment of nutritional status in dialysis patients is now considered mandatory.

While several studies have evaluated the body composition in the entire hemodialysis population,[2] no data are available in the subgroup of overweight patients. However, this issue is critical and must be addressed; indeed, great interest has recently focused on the overweight patients, which account for almost 40% of the hemodialysis population.[7] The previous studies have focused on the influence of the overweight status on survival; surprisingly, in spite of the major risk of death associated with excess weight in the healthy population,[8] a survival advantage of being overweight has been reported in HD patients.[7,9] In contrast, other authors have demonstrated that the risk of mortality

*Correspondence: B Guida, Department of Physiology, Faculty of Medicine, University 'Federico II' of Naples, Via Calata S. Francesco 12 B 80127 Napoli, Italy.
E-mail: bguida@unina.it
Received 28 November 1999; revised 7 June 2000; accepted 2 August 2000

and hospitalization increases with the increment of the value of body mass index (BMI, kg/m^2) when longer periods of follow-up are considered.[10] Acquisition of information on the nutritional status in overweight/obese HD patients may provide important insights into the relationship between the overweight status and the outcome in uremia.

In dialysis, mild to moderate malnutrition is not revealed by abnormalities of the common nutritional markers that become manifest only in the advanced stage of disease;[6,11,12] consequently, practical and sensible indicators of body composition are needed for clinical purposes. Most of the available methods for evaluating body composition, even though accurate, cannot easily be used in the clinical setting. Indeed, anthropometry that adequately assesses the nutritional status in dialysis[13] is not practical to perform on a routine basis.

Bioelectrical impedance analysis (BIA) is a new and simple indirect technique that analyzes the body composition by evaluating some electrical characteristics of the human body through the application of a low-amplitude alternating electrical current in the body.[14,15] BIA evaluates the impedance of the tissues to the electrical current by measuring the resistance (R), which is the pure opposition of the tissue to the flow of electrons, and the reactance (X_c), which reflects the capacitance of cell membranes and tissues interfaces. A further BIA variable of interest is the phase angle (PA) — the angular transformation of the X_c/R ratio[16] — which has been related to the extent of lean body mass.[17–19] BIA can be considered as an excellent alternative to the measurement of skinfold thickness since BIA variables correlate with anthropometric data.[20] Furthermore, this technique allows an early detection of abnormal nutritional status in physiological conditions as well as in a variety of pathological conditions, including uremia.[21–26] In particular, the alterations of PA, which is an independent predictor of death in uremic patients,[25,27,28] precede the changes of biochemical nutritional parameters.[25]

The current study was designed to gain insights into the influence of body size, as indicated by body mass index, upon body composition in hemodialysis patients. To this aim, we performed bioimpedance analysis and anthropometry in groups of patients with different BMI. Since BIA primarily measures body water content and assumes a constant hydration factor to predict lean body mass, we enrolled into the study only patients regularly achieving the prescribed dry weight.

Methods

Subjects

This investigation includes 50 patients (HD), 24 males and 26 females, with mean age 62.8 ± 9.2 y and BMI (kg/m^2) within the 18.5 – 35 range, kept on maintenance hemodialysis for at least 1 y. Thirty-eight age- and BMI-matched healthy subjects constituted the control group (CON, 17 male and 21 female, mean age: 63.3 ± 6.1 y). All the subjects gave their informed consent to the study, which was approved by the Ethical Committee of the Medical School of the University Federico II of Naples. Both patients and controls were divided into three groups according to the value of BMI:[29] 18.5 – 24.9 (normal-weight, NW); 25 – 29.9 (overweight, OW); ≥30 (obese, OB). All the study subjects were allowed *ad libitum* intake of energy and protein.

We selected hemodialysis patients with stable clinical conditions according to the following inclusion criteria: adult; anuric; absence of cancer, infection or any acute illness in the last 3 months; constancy in the last 3 months of dialysis dose and modality, dietary intakes, body weight and routine laboratory measurements. To exclude major alterations of hydration status, the optimal dry weight was accurately achieved in each patient according to clinical criteria: lowest weight at the end of HD session that the patient can tolerate without intradialysis symptoms (dizziness, cramps) and hypotension; absence of peripheral or pulmonary edema; and presence of normal blood pressure values during the interdialysis period in the absence of antihypertensive treatment.[30] Patients were studied after the mid-week hemodialysis session to further minimize any distortion in BIA measures caused by excess tissue fluid.

Patients were dialyzed in the supine position, with the vascular access being native arteriovenous fistula in all of them, for 240 min three times per week using cellulose membranes with surface area of 1.1 – 1.5 m^2. Blood and dialysate flow rates were 250 – 300 and 500 ml/min, respectively. The dialysis solution was bicarbonate-buffered, isotonic, with the temperature constantly kept around 37°C.

Body composition

The same investigators performed BIA and anthropometry measurements in all subjects. In patients the body composition measurements were obtained 30 min after the end of the hemodialysis session in order to allow a complete fluid re-equilibrium.

BIA. Single-frequency BIA was determined at 50 kHz and 800 μA with an impedance plethysmograph (*model BIA 101 RJL,* Akern, Firenze, Italy) according to the standard tetrapolar technique; to avoid artifacts, the electrodes were placed on feet, ankles, hands and wrists on the side of the body free from the vascular access.[31,32] Furthermore, to avoid the influence of fluid redistribution related to postural changes on BIA measures,[33] patients were studied while maintaining the supine position also after the end of HD session, and controls after lying in bed for at least 30 min.

The body composition measures were calculated from BIA (resistance and reactance) and anthropometric (body height and weight) variables, by using the software provided by the BIA machine (Akern/RJL Systems) as previously described.[18,34] This predictive model allows total body water (TBW), body fat mass (BIA-FM) and fat-free mass

(BIA-FFM), body cell mass (BCM), and extra- and intracellular water (ECW, ICW) to be calculated.

Anthropometry. Anthropometric measurements included body weight (BW), height and skinfold thickness (ST). Body mass index (BMI), which is considered a reliable parameter to estimate obesity as risk factor,[35] was calculated as the ratio body weight/height^2 (in kg/m^2).[29] Skinfold thickness was determined by Holtain–Tanner–Whitehouse calipers at the biceps, triceps, subscapular and suprailiac side, according to Loman, Roche and Martorell and the FFM (A-FFM) was calculated from the sum of these four skinfolds.[36]

Biochemical and dialysis data

In patients, blood samples were drawn before the dialysis session to measure leucocyte number, hematocrit (Ht), and the plasma levels of urea (reported as blood urea nitrogen, BUN), albumin, $\alpha 2$ globulin, C reactive protein, creatinine and cholesterol. A sample was also obtained immediately after the end of HD session to measure the BUN value. The Kt/V which is a measure of dialysis dose, was calculated by the following equation:[37] $-\ln(R-0.008\times T_d)+(4-3.5R)\ UF/W$, where R = BUN post-HD/BUN pre-HD, T_d = HD time (hours), UF = ultrafiltration volume, W = body weight at end of dialysis session (kg); Kt/V is a dimensionless measure of dialysis dose, where K is the urea dialysate clearance (expressed in ml/ml), t is treatment time (in minutes) and V is the body volume cleared by urea at a rate K (V approximately equals total body water, that is, 58% of dry weight). The protein intake was calculated as protein catabolic rate (PCR; g/kg ideal body weight/day), by means of the standard formula, $2.03\ \Delta C+0.16$, where ΔC is the change in BUN during dialysis ($\Delta C = C_0 - C_t$, where C_0 = predialysis BUN and C_t = postdialysis BUN, mg/ml) that in steady-state is equal to the interdialysis rise in BUN. This equation is based on the assumption that C_0 is constant if both urea generation (ΔC) and dose of dialysis (Kt/V) remain constant.[38]

Statistics

Values are given as mean ± s.d. Differences between patients and controls were tested by two-tailed Student's *t*-test for unpaired data. Analysis of variance and Bonferroni *post-hoc* test were used for the comparison among the three different BMI group. A $P < 0.05$ was considered significant.

Results

By grouping the study subjects on the basis of the BMI value, we found that seven HD patients were obese (12%), while 16 were overweight (32%); in CON, the respective values were 31% and 31%.

Table 1 shows the anthropometric and bioelectrical data. The values of body weight and BMI were comparable in the three BMI categories, both in patients and in age- and gender-matched controls; also ECW% was similar in HD and CON, confirming the absence of over- or dehydration state in patients.

Body composition data are reported in Table 1. In controls, BIA-measured FFM% and BCM%, as well as antropometry-measured FFM%, decreased in the obese group in comparison with the normal weight group ($P < 0.001$). Similarly, in patients FFM-A%, FFM-BIA% and BCM% decreased

Table 1 Individual, anthropometric (A) and bioimpedance analysis (BIA) data in hemodialyzed patients (HD, $n = 50$), and in controls (CON, $n = 38$) grouped by the value of body mass index

	Normal weight		*Overweight*		*Obese*	
	HD (n = 27)	*CON (n = 14)*	*HD (n = 16)*	*CON (n = 12)*	*HD (n = 7)*	*CON (n = 12)*
Age (y)	57.7 ± 10.6	63.4 ± 5.5	64.7 ± 9.1	61.8 ± 7.9	66.2 ± 9.4	65.8 ± 5.1
Gender (F%)	52	50	50	58	57	58
BW (kg)	59.3 ± 6.5	57.2 ± 6.0	68.3 ± 9.2†	71.9 ± 8.7†	76.7 ± 7.9†‡	85.2 ± 9.2†‡
BMI (kg/m^2)	22.0 ± 1.7	22.9 ± 1.3	27.1 ± 1.7†	27.6 ± 1.2†	33.9 ± 4.4†‡	33.3 ± 2.3†‡
medians	22.8	23.0	26.1	28.0	33.2	33.5
ECW%	37.4 ± 5.1	39.7 ± 2.9	38.0 ± 4.9	39.3 ± 3.5	38.1 ± 2.0	40.2 ± 2.2
FFM-BIA (kg)	40.9 ± 6.2	41.2 ± 4.1	41.0 ± 7.3*	49.2 ± 9.0†	42.5 ± 3.0*	54.7 ± 9.0†
FFM-A (kg)	44.4 ± 6.8	41.0 ± 3.8	45.3 ± 8.6	49.7 ± 7.3†	44.5 ± 5.9*	54.2 ± 7.5†
FFM-BIA %	69.0 ± 6.9	72.1 ± 3.7	59.0 ± 7.7*†	68.9 ± 4.6	56.9 ± 3.2*†	64.5 ± 5.2†‡
FFM-A%	75.1 ± 7.4	71.7 ± 2.5	68.9 ± 5.9†	69.2 ± 4.3	59.0 ± 2.7*†‡	63.7 ± 3.2†‡
FM-BIA (kg)	18.4 ± 4.8	15.9 ± 6.8	27.6 ± 7.3*†	21.8 ± 6.2†	31.8 ± 5.2†	30.2 ± 4.8†‡
FM-A (kg)	14.9 ± 5.2	16.1 ± 2.8	21.8 ± 1.2†	21.9 ± 5.3†	32.2 ± 2.1†‡	30.0 ± 4.1†‡
FM-BIA%	30.9 ± 6.9	27.8 ± 3.6	40.3 ± 7.8*†	31.0 ± 4.5	43.1 ± 3.2*†	35.5 ± 5.2†‡
FM-A%	25.1 ± 7.4	28.2 ± 2.5	31.0 ± 5.9†	30.8 ± 4.0	40.9 ± 2.6*†‡	36.1 ± 3.5†‡
BCM-BIA (kg)	20.9 ± 4.6	21.2 ± 2.9	19.3 ± 3.6*	25.1 ± 5.2†	19.6 ± 1.9*	27.4 ± 4.5†
BCM-BIA%	34.9 ± 6.3	37.0 ± 3.3	27.0 ± 4.5*†	35.2 ± 3.8	26.3 ± 3.0*†	32.2 ± 3.2†‡

*$P < 0.05$ *vs* CON; †$P < 0.05$ *vs* normal weight; ‡$P < 0.05$ *vs* overweight.
Abbreviations: BW, body weight; BMI, body mass index; ECW, extra-cellular water; FFM, fat-free mass; FM, fat mass; BCM, body cell mass.

as compared to patients with normal BMI, with the difference being significant not only in the obese but also in the overweight group. In HD, the decrease of percentage FFM and BCM was coupled with a major increase of adipose tissue, as indicated by the higher fractional fat mass (FM), with respect to CON in both overweight and obese, but not normal-weight, groups. Furthermore, when BCM was measured as absolute value, we did not find any significant difference among the three BMI categories in patients, while a significant increment of absolute BCM value was detected in parallel with the increase of body weight in controls. We found a similar pattern of changes for the absolute value of FFM measured by both anthropometry and BIA. When comparing CON and HD groups sorted for BMI, we did not detect significant differences in BCM and FFM between normal-weight subgroups; on the contrary, both parameters were significantly lower in overweight and obese patients ($P < 0.01$), testifying the major reduction of lean mass in hemodialyzed patients with higher body size.

Interestingly, we observed a parallel decrease of phase angle in overweight ($P < 0.005$) and obese ($P < 0.02$) HD patients, while it did not vary in the three CON groups (Figure 1).

Table 2 shows dialysis data and biochemical markers of nutritional status in the three groups of patients with different BMI. Dialysis age and *Kt/V* values were comparable in the three groups. Serum albumin, blood urea nitrogen (BUN) and protein catabolic rate (PCR) were significantly reduced in obese with respect to normal-weight patients; also the interdialysis weight gain (IDWG), was numerically diminished at higher BMI. Of note, no significant difference in the biochemical markers of nutritional status was detected between normal weight and overweight patients. The presence of a major inflammatory/infectious state in the three groups of patients was excluded on the basis of the normal values of leukocyte count, $\alpha 2$ globulin and C reactive protein levels.

Table 2 Dialysis biochemical and nutritional data in hemodialyzed patients grouped by the value of body mass index

	Normal weight (n = *27*)	*Overweight* (n = *16*)	*Obese* (n = *7*)
Kt/V	1.0 ± 0.1	1.1 ± 0.2	1.1 ± 0.3
Dialysis age (months)	43 ± 25	37 ± 24	38 ± 23
Albumin (g/dl)	4.1 ± 0.3	4.0 ± 0.3	3.6 ± 0.5*†
Creatinine (mg/dl)	10.2 ± 2.3	9.1 ± 1.2	10.6 ± 2.1†
Cholesterol (mg/dl)	190 ± 38	203 ± 36	205 ± 39
Hematocrit (%)	33.6 ± 3.5	32.8 ± 2.9	32.4 ± 3.4
PCR	1.3 ± 0.3	1.1 ± 0.4	1.0 ± 0.1*
BUN (mg/dl)	89.1 ± 19.8	77.2 ± 19.1	70.3 ± 19.1*
IDWG (% BW)	5.0 ± 1.6	4.7 ± 1.5	4.0 ± 1.3
Leucocytes (n/mm^2)	5678 ± 1241	6144 ± 1093	5932 ± 998
$\alpha 2$ (g/dl)	0.76 ± 0.06	0.82 ± 0.03	0.79 ± 0.05
Crp (mg/ml)	0.28 ± 0.18	0.26 ± 0.19	0.25 ± 0.13

*$P < 0.05$ *vs* normal-weight; †$P < 0.05$ *vs* overweight.
Abbreviations: PCR, protein catabolic rate; BUN, blood urea nitrogen; IDWG, inter-dialysis weight gain; $\alpha 2$, serum $\alpha 2$ globulin; Crp, C reactive protein.

Table 3 depicts the correlation coefficients obtained by plotting the BIA data (PA and BCM) with the anthropometric (BMI and FFM) and biochemical markers of nutritional status. In HD patients, FFM-A and standard laboratory markers (creatinine and urea nitrogen) correlated with PA and BCM, while BMI significantly correlated only with PA. On the contrary, in controls, FFM-A and BMI correlated with BCM, whereas no significant correlation with PA was detected.

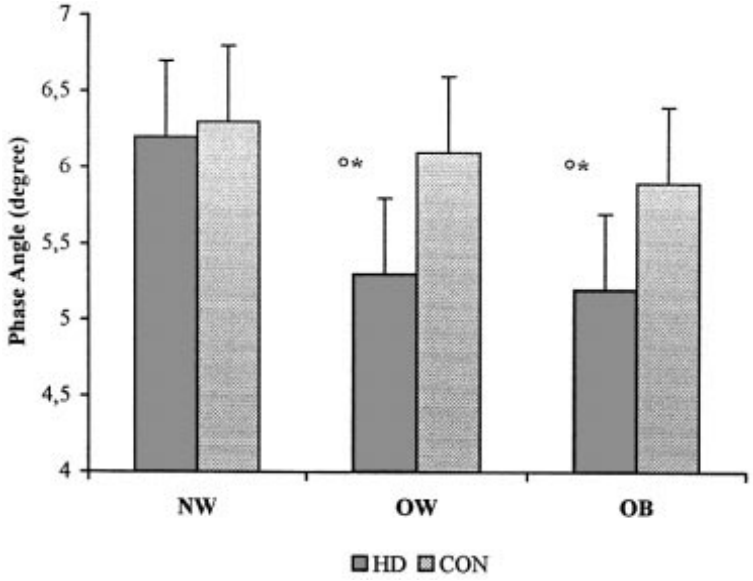

Figure 1 Phase angle in hemodialyzed patients (HD) and controls (CON), grouped in normoweight (NW), overweight (OW) and obese (OB). °$P < 0.05$ *vs* NW; *$P < 0.05$ *vs* CON.

Table 3 Linear correlation analysis between bioimpedance data and nutritional variables in hemodialyzed patients ($n = 50$) and controls ($n = 38$)

	BCM		*PA*	
	r	P	r	P
Controls				
BMI	0.52	0.001	−0.23	0.17
FFM-A	0.80	0.001	−0.08	0.64
Patients				
BMI	−0.16	0.24	−0.34	< 0.02
Creatinine	0.43	< 0.002	0.53	< 0.0001
Cholesterol	−0.32	< 0.05	−0.34	< 0.05
Albumin	0.41	< 0.01	0.51	< 0.001
BUN	0.38	< 0.01	0.37	< 0.01
PCR	0.28	0.09	0.32	< 0.05
FFM-A	0.65	< 0.0001	0.47	< 0.01

Abbreviations: BCM, body cell mass; PA, phase angle; BMI, body mass index; BUN, blood urea nitrogen; PCR, protein catabolic rate; FFM-A anthropometry-derived fat-free mass.

Discussion

In this study, 44% of the 50 selected hemodialysis patients were overweight or obese, with 12% of such individuals being obese. The size of the sample is small, nevertheless, the aim of the study was to examine body composition in HD patients with a BMI value above the normal range, rather than to assess the prevalence of the phenomenon.

In recent years, a great effort has been made to find clinical tools for body composition analysis in HD patients. Sophisticated techniques, such as neutron activation analysis or total body potassium, are accurate and reliable methods but are expensive and not available for clinical purposes;[39,40] anthropometric measurements also accurately reflect nutritional status and body composition in dialysis,[13,41] but are time-consuming and not practical to take on a routine basis. On the other hand, clinical and laboratory parameters are easy to collect but imprecise.[11,42] The main biochemical parameters suggestive of protein-energy malnutrition in dialysis, such as serum albumin, dietary protein intake (indicated by the protein equivalent of total nitrogen appearance or PCR) and predialysis serum urea nitrogen correlate with morbidity or mortality,[4,5,11] these markers, however, must be interpreted with caution and, more important, alterations of such indexes often become manifest only late in the course of the deteriorating nutritional status in dialysis, that is, after severe malnutrition is established.[6,11,12]

Bioelectrical impedance analysis (BIA) allows a fast and sensitive bedside assessment of human body composition.[14,21] The tetrapolar bioelectrical impedance analysis described by Shizgal and Jodin *et al* refers to a three-compartment model body cell mass (BCM), body fat (FM), and extracellular mass (ECM).[15,21] BIA has been cross-validated in normals, malnourished subjects and HD patients as well,[14,15,17,21–23,43,44] by means of BIA indexes, malnutrition is characterized by a decreased BCM at expense of increased ECW, that is, by the rise of the ECW – BCM ratio. In pregnant women the changes of BIA-derived FFM and FM have been verified by the isotope dilution technique;[45] similarly, in adolescents with malnutrition due to anorexia, BIA appears to be better at predicting changes of body composition than the assessment of weight alone or weight in combination with height.[46] Of note is the association in patients malnourished because of surgery, cancer, sepsis or anorexia of BCM decline with the reduction of PA value.[47–51]

BIA is an adequate and easily accessible clinical tool for monitoring nutritional status also in uremic patients.[17,20,24–26,52] Specifically, in HD patients BIA-derived BCM and TBW strictly correlate with DEXA-derived BCM and D_2O dilution-measured TBW.[17] Furthermore, in these patients, the extent of FFM and FM assessed by BIA is comparable with the data obtained by measuring skinfolds thickness.[53,54] Interestingly, in dialysis the value of PA also provides information on body composition; the X_c/R ratio is in fact inversely related to the ECW/TBW ratio.[17]

Early work has demonstrated that in HD patients, as in non-uremic subjects, BIA variables and laboratory markers of nutritional status significantly correlate.[55] The present study extends these previous finding to the oversize dialytic population. We observed a direct correlation between bioimpedance measures and the traditional anthropometric and laboratory markers of nutritional status. Notably, these results were obtained in the absence of major alterations of hydration status, as required by the experimental design and confirmed by the constancy of ECW%. Thus, it is reasonable to assume that in hemodialysis patients kept at dry weight, BIA-derived PA, FFM and BCM are reliable indices of body composition.

The major finding of the study is that, while in non-uremic controls the BMI increment is associated with unvaried PA, in HD patients a significant decrease of PA occurs at higher BMI. The change of PA is not characterized by a linear pattern, being significantly lower in the overweight state and not worsened in obese patients. This abnormality is probably critical; indeed, in patients with pre-dialytic chronic renal failure, the initial impairment of body composition is revealed by the decline of phase angle that is associated with a reduced survival, even if the usual biochemical markers nutritional status are unvaried.[27] Similarly, the reduction of PA is independently associated with an increased risk of death also in the HD population.[25,28] Therefore, the decline of PA detected in HD patients with higher BMI is of clinical relevance since it possibly reveals a condition of impaired nutritional status and increased risk of death.

In both overweight and obese HD patients, a significant reduction of BIA-measured BCM% and FFM% was also detected. This finding was associated with unchanged BCM and FFM as absolute values and with a major increase of BIA-derived FM. On the contrary, in controls both absolute BCM and FFM values increased at higher BMI. Indeed, in most obese non-uremic individuals the increment of fat mass is

associated with a parallel increase of lean mass, each change accounting for almost half of the excess weight;[56] similarly, non-uremic individuals show a proportional increment of FFM and FM during intentional overfeeding.[57] The pattern of body composition changes observed in our patients, however, is not surprising; indeed, it has been previously demonstrated that in HD patients, hyperleptinemia, which is typically found in uremic obese,[58] is associated with the isolated increase of fat body mass.[59] Therefore, the observation of a lower BCM% and FFM% coupled with the increase of FM suggests that oversize HD patients, at variance with non-uremic subjects, are affected by a poor preservation of body composition characterized by a major increase of fat mass at the expense of reduced lean mass. This hypothesis is supported by the decline of anthropometry-measured FFM. Interestingly, in obese, but not overweight, patients a significant reduction of serum albumin level was also detected.

The reasons underlying such abnormalities of nutritional status in overweight HD patients are not readily apparent. In this study the main causes of impaired nutritional status, such as age,[60] treatment time, dose and modalities of dialysis, inflammatory status[13] and time on dialysis,[61] were excluded. On the contrary, we detected a different protein intake across the three BMI groups. In fact, the values of PCR and pre-dialysis BUN slightly diminished in overweight patients and were significantly lower in obese patients. In addition, we found in these patients a numerical decrement of the interdialytic weight gain, that is a parameter related with the nutrient intake and nutritional status in HD.[62,63] These data therefore indicate a spontaneous reduction of protein intake in overweight hemodialysis patients. Since the nutrient intake correlates with the BIA estimates of BCM and FFM,[51] the reduced protein intake may account, at least in part, for the impaired nutritional status.

In conclusion, in overweight and obese HD patients, BIA-derived FFM, BCM and PA are significantly lower with respect to the values detected in normal-weight patients and BMI-matched non-uremic controls. These abnormalities of body composition are coupled with the reduction of anthropometry measures of lean mass as well as with a decrease of protein intake which, however, becomes evident only in the obese. Therefore, overweight and obese HD patients are at risk of protein malnutrition in spite of excessive energy intake and apparent well-being. BIA may be considered a diagnostic tool to early detect such a condition.

References

1 Kopple JD. Dietary protein and energy requirement in ESRD patients. *Am J Kidney Dis* 1998; **32**(Suppl 4): 97–104.
2 Ikizler TA, Hakim RM. Nutrition in end-stage renal disease. *Kidney Int* 1996; **50**: 343–357.
3 Schoenfeld PY, Henry RR, Laird NM, Roxe DM. Assessment of nutritional status of the National Cooperative Dialysis Study population. *Kidney Int* 1983; **13**(Suppl): S80–S88.
4 Acchiardo SR, Moore LW, Latour PA. Malnutrition as the mean factor in morbidity and mortality of hemodialysis patients. *Kidney Int* 1983; **16**(Suppl): S199–S203.
5 Owen WF, Lew NL, Liu Y, Lowrie EG, Lazarus JL. The urea reduction ratio and serum albumin concentration as predictors of mortality in patients undergoing hemodialysis. *New Engl J Med* 1993; **329**: 1001–1006.
6 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.
7 Fleischmann E, Teal N, Dudley J, May W, Bower JD, Salahudeen AK. Influence of excess weight on mortality and hospital stay in 1346 hemodialysis patients. *Kidney Int* 1999; **55**: 1560–1567.
8 Rissanen A, Heliovaara M, Knekt P, Aromaa A, Reunanen A, Maatela J. Weight and mortality in Finnish men. *J Clin Epidemiol* 1989; **42**: 781–789.
9 Kopple JD, Zhu X, Lew NL, Lowrie EG. Body weight-for-height relationships predict mortality in maintenance hemodialysis patients. *Kidney Int* 1999; **56**: 1136–1148.
10 Kaizu Y, Tsunega Y, Yoneyama T, Sakao T, Hibi I, Miyaji K, Kumagai H. Overweight as another nutritional risk factor for the long-term survival of non-diabetic hemodialysis patients. *Clin Nephrol* 1998; **50**: 44–50.
11 Oksa H, Ahonen K, Pasternak A, Marnela KM. Malnutrition in hemodialysis patients. *Scand J Urol Nephrol* 1991; **25**: 157–161.
12 Cano N, Fernandez JP, Lacombe P, Lankester M, Pascal S, Defayolle M, Labastie J, Saingra S. Statistical selection of nutritional parameters in hemodialyzed patients. *Kidney Int* 1987; **22**(Suppl): S178–S180.
13 Williams AJ, McArley A. Body composition, treatment time, and outcome in hemodialysis patients. *J Ren Nutr* 1999; **9**: 157–162.
14 Abu Khaled M, McCutcheon MJ, Reddy S, Pearman PL, Hunter GR, Weinsier RL. Electrical impedance in assessing human body composition: the BIA method. *Am J Clin Nutr* 1988; **47**: 789–792.
15 Joidin RR, Trott SG, Shizgal HM. Determination of body composition from body electrical impedance. *Surg Forum* 1988; **39**: 50.
16 NIH Consensus Statement. Bioelectrical impedance analysis in body composition measurement. *Nutrition* 1996; **12**: 749–759.
17 Chertow GM, Lowrie EG, Wilmore DW, Gonzalez J, Lew NL, Ling J, Leboff MS, Gottlieb MN, Huang W, Zebrowski B. Nutritional assessment with bioelectrical impedance analysis in maintenance hemodialysis patients. *J Am Soc Nephrol* 1995; **6**: 75–81.
18 Kotler DP, Burastero S, Wang J, Pierson RN Jr. Prediction of body cell mass, fat-free mass, and total body water with bioelectrical impedance analysis: effect of race, sex, and disease. *Am J Clin Nutr* 1996; **64**(Suppl): S489–S497.
19 Jacob DO. Bioelectrical impedance analysis: implication for clinical practice. *Nutr Clin Pract* 1997; **12**: 204–210.
20 Madore F, Wuest M, Ethier JH. Nutritional evaluation of hemodialysis patients using an impedance index. *Clin Nephrol* 1994; **41**: 377–382.
21 Shizgal HM. Validation of the measurement of body composition from whole body bioelectric impedance. *Infusion Therapie* 1990; **17**: 67–74.
22 Lukaski HC, Johnson PE, Lykken GL. Assessment of fat free mass using bio-electrical impedance measurements of the human body. *Am J Clin Nutr* 1985; **41**: 810.
23 Kushner RI, Schoeller DA. Estimation of total body water by bioelectrical impedance analysis. *Am J Clin Nutr* 1986; **44**: 417.
24 Dumler F. Use of bioelectric impedance analysis and dual-energy X-ray absorptiometry for monitoring the nutritional status of dialysis patients. *ASAIO J* 1997; **43**: 256–260.
25 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.
26 Ho LT, Kushner RF, Schoeller DA, Gudivaka R, Spiegel DM. Bioimpedance analysis of total body water in hemodialysis patients. *Kidney Int* 1994; **46**: 1438–1442.

27 Bellizzi V, Terracciano V, Gaudiano G, Cianciaruso B, De Nicola L, Di Iorio B. Early changes of body composition detected by bioimpedance analysis can predict survival in CRF. *J Am Soc Nephrol* 1998; **9**: 140A (abstract).
28 Chertow GM, Jacob DO, Lazarus JM, Lew NL, Lowrie EG. Phase angle predicts survival in hemodialysis patients. *J Renal Nutr* 1997; **7**: 204–207.
29 Willet WC, Dietz WH, Colditz GA. Guidelines for healthy weight. *New Engl J Med* 1999; **341**: 427–434.
30 Charra B, Calemard E, Ruffet M, Chazot C, Terrat JC, Vanel T, Laurent G. Survival as an index of adequacy of dialysis. *Kidney Int* 1992; **41**: 1286–1291.
31 Guidivaka R. Effect of position, electrode placement, and time on prediction of total body water by multifrequency bioelectrical impedance analysis. *Age Nutr* 1994; **5**: 111–117.
32 Di Iorio BR, Terracciano V, Bellizzi V. Bioelectrical impedance measurement: errors and artifacts. *J Ren Nutr* 1999; **9**: 192–197.
33 Zhu F, Schneditz D, Levin NW. Sum of segmental bioimpedance analysis during ultrafiltration and hemodialysis reduces sensitivity to changes in body position. *Kidney Int* 1999; **56**: 692–699.
34 Kushner RF, Kunigk A, Alspaugh M, Andronis PT, Leitch CA, Schoeller DA. Validation of bioelectrical-impedance analysis as a measurement of change in body composition in obesity. *Am J Clin Nutr* 1990; **52**: 219–223.
35 Kato M, Shimazu M, Moriguchi S, Kishino Y. Body mass index (BMI) is a reliable index to estimate obesity as a risk factor for deteriorating health. *J Exp Med* 1996; **43**: 1–6.
36 Lohman TG, Roche AF, Martorell R. *Anthropometric Standardization Reference Manual*. Library of Congress Cataloging-in-Publication Data, 1988.
37 Daugirdas JT. Second generation logarithmic estimates of single pool variable volume *Kt/V*: an analysis of error. *J Am Soc Nephrol* 1993; **4**: 1205–1213.
38 Gotch FA, Sargent JA. A mechanistic analysis of the National Corporation Dialysis Study (NCDS). *Kidney Int* 1995; **28**: 526–34.
39 Cohn SH, Brennan BL, Yasumura S, Vartsky D, Vaswani AN, Ellis KJ. Evaluation of body composition and nitrogen content of renal patients on chronic dialysis as determined by total body neutron activation. *Am J Clin Nutr* 1983; **38**: 52–58.
40 Lukasky HC, Mendez J, Buskirk ER, Cohn SH: A comparison of methods of assessment of body composition including neutron activation analysis of total body nitrogen. *Metabolism* 1981; **30**: 777–782.
41 Nelson EE, Hong CD, Pesce AL, Peterson DW, Singh S, Pollack VE. Anthropometric norms for the dialysis population. *Am J Kidney Dis* 1990; **16**: 32–37.
42 Blumenkrantz MJ, Kopple JD, Gutman RA, Chan YK, Barbour GL, Roberts C, Shen FH, Gandhi VC, Tucker CT, Curtis FK, Coburn JW. Methods for assessing nutritional status of patients with renal failure. *Am J Clin Nutr* 1980; **33**: 1567–1585.
43 Lukaski Hc, Bolonchuk WW, Hall CB, Siders WA. Validation of tetrapolar bioelectrical impedance method to assess body composition. *J Appl Physiol* 1986; **60**: 1327–1332.
44 Kotler DP, Rosenbaum K, Allison DB, Wang J, Pierson RN Jr. *J Parenteral Enteral Nutr* 1999; **23**: 345–349.
45 Lukaski HC, Siders WA, Nielsen EJ, Hall CB. Total body water in pregnancy: assessment by using bioelectrical impedance. *Am J Clin Nutr* 1994; **59**: 578–585.
46 Pencharz PB, Azcue M. Use of bioelectrical impedance analysis measurements in the clinical management of malnutrition. *Am J Clin Nutr* 1996; **64**(Suppl): S485–S488.
47 Shizgal HM. Body composition of patients with malnutrition and cancer. *Summ Meth Assess Cancer* 1985; **55**: 250–253.
48 Shizgal HM. The effect of malnutrition on body composition. *Surg Gynecol Obstet* 1981; **152**: 22–26.
49 Scalfi L, Di Biase G, Coltorti A, Contaldo F. Bioimpedance analysis and resting energy expenditure in undernourished and reefed anorectic patients. *Eur J Clin Nutr* 1993; **47**: 61–76.
50 Polito A, Cuzzolaro M, Raguzzini A, Censi L, Ferro-Luzzi A Body composition changes in anorexia nervosa. *Eur J Clin Nutr* 1998; **52**: 655–662.
51 Robert S, Zarowitz BJ, Hyzy R, Eichenhorn M, Peterson EL, Popovich J Jr. Bioelectrical impedance assessment of nutritional status in critically ill patients. *Am J Clin Nutr* 1993; **57**: 840–844.
52 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 Electrolyte Metab* 1992; **18**: 284–287.
53 Abrahamsen B, Hansen TB, Hogsberg IM, Pedersen FB, Beck-Nielsen H. Impact of hemodialysis on dual X-ray absorptiometry, bioelectrical impedance measurements, and anthropometry. *Am J Clin Nutr* 1996; **63**: 80–86.
54 Oe B, de Fijter CW, Oe PL, Stevens P, de Vries PM. Four-site skinfold anthropometry versus body impedance analysis in assessing nutritional status of patients on maintenance hemodialysis: which method is to be preferred in routine patient care? *Clin Nephrol* 1998; **49**: 180–185.
55 Chertow GM, Lazarus JM, Lew NL, Ma L, Lowrie EG. Bioimpedance norms for the hemodialysis population. *Kidney Int* 1997; **52**: 1617–1621.
56 Webster JD, Hesp R, Garrow JS. The composition of excess weight in obese women estimated by body density, total body water and total body potassium. *Hum Nutr Clin Nutr* 1984; **38**: 299–306.
57 Forbes GB, Welle SL. Lean body mass in obesity. *Int J Obes* 1983; **7**: 99–107.
58 Nishikawa M, Takagi T, Yoshikawa N, Shouzu A, Murakami T, Kono M, Owae H, Tanaka K, Iwasaka T, Inada M. Measurement of serum leptin in patients with chronic renal failure on hemodialysis. *Clin Nephrol* 1999; **51**: 296–303.
59 Nishizawa Y, Shoji T, Tanaka S, Yamashita M, Morita A, Emoto M, Tabata T, Inoue T, Morii H. Plasma leptin level and its relationship with body composition in hemodialysis patients. *Am J Kidney Dis* 1998; **31**: 655–661.
60 Biasioli S, Foroni R, Petrosino L, Cavallini L, Zambello A, Cavalcanti G, Talluri T. Effect of aging on the body composition of dialyzed subjects. Comparison with normal subjects. *ASAIO J* 1993; **39**: M596–M601.
61 Chertow GM, Johansen KL, Lew N, Lazarus M, Lowrie EG. Vintage, nutritional status and survival in hemodialysis patients. *Kidney Int,* 2000; **57**: 1176–1181.
62 Sherman RA, Cody RP, Rogers ME, Solanchick JC. Interdialytic weight gain and nutritional parameters in chronic hemodialysis patients. *Am J Kidney Dis,* 1995; **25**: 578–583.
63 Testa A, Beaud J-M. The other side of the coin; interdialytic weight gain as an index of good nutrition. *Am J Kidney Dis* 1998; **31**: 830–834.

Appendix

List of abbreviations

BIA, bioelectrical impedance analysis;
HD, hemodialysis;
R, resistance;
Xc, reactance;
PA, phase angle;
TBW, total body water;
BCM, body cell mass;
FFM, fat free mass;
FM, fat mass;
ECW%, extracellular water as a percentage of total body water;
BCM%, body cell mass as a percentage of body weight;
FFM%, fat free mass as a percentage of body weight;
FM%, fat mass as a percentage of body weight;
BMI, body mass index.