

# Relationship of bioelectrical impedance parameters to nutrition and survival in peritoneal dialysis patients

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## Relationship of bioelectrical impedance parameters to nutrition and survival in peritoneal dialysis patients.

**Background.** Malnutrition is highly prevalent in peritoneal dialysis (PD) patients and is associated with higher mortality in these patients. In this study, we have prospectively examined the relationship of bioimpedance indexes to the nutritional status and survival in PD patients.

**Methods.** We enrolled 48 PD patients beginning in November 2000. On enrollment, bioelectrical impedance analysis (BIA) (BIA-101; RJL/Akern, Clinton Township, MI, USA) was performed and monthly blood was analyzed for biochemical markers, including prealbumin. Patients were followed until April 2003.

**Results.** The mean age of PD patients was  $51 \pm 15$  (SD) years. Fifty-eight percent of the patients were female and 23% of the patients were diabetic. Mean body mass index (BMI) was  $25.7 \pm 5.0$  kg/m<sup>2</sup>. Mean resistance, reactance, and phase angle were  $521 \pm 104$  ohms,  $57 \pm 19$  ohms, and  $6.16 \pm 1.6$  degrees, respectively. During the study period, 8 patients (17%) expired. The Kaplan-Meier method was used to compute observed survival. The cumulative observed survival of PD patients with enrollment phase angle greater than or equal to 6 degrees was significantly higher ( $P = 0.008$ ) than that of patients with phase angle less than 6. Using Cox's multivariate regression analysis, phase angle was an independent predictor (relative risk = 0.39,  $P = 0.027$ ) of more than two years' survival in PD patients. Serum prealbumin was directly correlated with phase angle ( $r = 0.54$ ,  $P < 0.0001$ ), reactance ( $r = 0.55$ ,  $P < 0.0001$ ), and resistance ( $r = 0.29$ ,  $P = 0.06$ ).

**Conclusion.** BIA indexes reflect nutritional status and may be useful in monitoring nutritional status in PD patients. Phase angle is a strong prognostic index in PD patients. It is useful to incorporate prealbumin and BIA parameters in the regular assessment of PD patients, whose survival may be improved by better management of malnutrition and overall health status.

Bioelectrical impedance analysis (BIA) is a quick, inexpensive, safe, and noninvasive method for estimating body composition and nutritional status in various patient populations [1–5]. The use of BIA to measure body

composition and nutritional status in hemodialysis (HD) and peritoneal dialysis (PD) patients has been reported by several workers [6–11].

Protein energy malnutrition is highly prevalent in PD patients and is a strong risk factor for morbidity and mortality in these patients [12]. Decreased levels of serum nutritional markers such as albumin, creatinine, cholesterol, and prealbumin are associated with increased mortality in these patients [13–15]. Because of its rapid turnover rate, short half-life, and small pool size, serum prealbumin is a highly sensitive marker of nutritional status and a useful tool in predicting survival in PD patients. There is little information concerning the relationship between prealbumin and BIA parameters in PD patients. The principal objectives of the current study were to examine the relations among BIA parameters and laboratory surrogates of nutritional status and associations of BIA parameters with survival in PD patients.

## METHODS

### Patients

We enrolled 48 PD patients into the study over the period beginning in November of 2000 to October of 2002. All patients were followed through April 2003. On enrollment, demographic and clinical data collected included age, race, gender, diabetic status, etiology of end-stage renal disease (ESRD), and total months on dialysis at enrollment.

### Laboratory analysis

Nonfasting blood samples were collected at a routine monthly visit, and a multiphasic biochemistry screen, including albumin, creatinine, blood urea nitrogen (BUN), total cholesterol, and prealbumin was performed. Albumin concentration was determined by the bromocresol green method. Prealbumin was measured by immunoturbidimetric method (Spectra East, Rockleigh, NJ, USA).

**BIA study.** On the day of the blood collection, patients underwent BIA analysis (BIA-101;RJL/Akern Systems,

**Key words:** peritoneal dialysis, prealbumin, bioelectrical impedance, outcomes.

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Clinton Township, MI, USA). This is an inexpensive piece of equipment that takes only a few minutes to use. BIA measurements were conducted by the same operator using an impedance plethysmograph (800 mA and 50 kHz). Patients' electrical impedance values, resistance, reactance, and phase angle were measured, and the body composition was determined using Cyprus 1.0 (BIA-101;RJL/Akern Systems).

### Statistical analysis

Continuous variables were reported as mean  $\pm$  SD. Correlations were reported as either the Pearson correlation coefficient or the Spearman rank correlation coefficient. Patient survival was analyzed, with death considered as the final event. Transfer to another center or switch of dialysis modality was regarded as censored information. Observed survival of PD patients was computed by Kaplan-Meier method [16]. Log-rank testing was used to compare survival curves. Survival was also evaluated using univariate and multivariate Cox regression analysis. Calculations were performed using SPSS for Windows 10.0.1 (SPSS, Inc., Chicago, IL, USA).

## RESULTS

### Demographics and patient characteristics

On study entry, the mean age of PD patients was  $51 \pm 15$  (SD) years. Twenty-three percent of the patients were diabetic, and 58% were female. The mean time on PD at enrollment was  $51 \pm 44$  (SD) months. The ethnic composition of the population was 69% African American, 21% Hispanic, 8% white, and 2% other. The etiology of ESRD was as follows: 15% diabetes; 40% hypertension; 13% glomerulonephritis; 6% polycystic kidney disease; 2% obstruction; 6% HIV; and 18% other/unknown. The mean and maximum follow-ups were 1.88 and 2.44 years, respectively.

### Laboratory data

The mean enrollment albumin was  $3.77 \pm 0.61$  g/dL, creatinine  $12.0 \pm 3.9$  mg/dL, total cholesterol  $205 \pm 36$  mg/dL, BUN  $48 \pm 16$  mg/dL, and prealbumin  $41.8 \pm 11.6$  mg/dL. Mean weight, body mass index (BMI), and body cell mass (BCM) were  $160 \pm 35$  (SD) lbs,  $25.7 \pm 4.9$  kg/m<sup>2</sup>, and  $53.5 \pm 15.3$  lbs, respectively. Mean resistance, reactance, and phase angle were  $521 \pm 104$  ohms,  $57 \pm 19$  ohms, and  $6.2 \pm 1.6$  degrees, respectively.

### Relationships between bioimpedance and nutritional parameters

Correlations between BIA parameters and nutritional markers are shown in Table 1. Resistance was correlated with body weight ( $r = -0.58$ ,  $P < 0.0001$ ), BMI ( $r = -0.39$ ,  $P = 0.006$ ), and BCM ( $r = -0.61$ ,  $P < 0.0001$ ). Resistance did not correlate with any serum nutritional

markers. Reactance was significantly correlated with prealbumin ( $r = 0.55$ ,  $P < 0.0001$ ) and albumin ( $r = 0.55$ ,  $P < 0.0001$ ). Phase angle correlated with BCM ( $r = 0.41$ ,  $P = 0.004$ ), prealbumin ( $r = 0.54$ ,  $P < 0.0001$ ), albumin ( $r = 0.54$ ,  $P < 0.0001$ ), and BUN ( $r = 0.46$ ,  $P = 0.002$ ). Reactance ( $r = -0.37$ ,  $P = 0.01$ ) and phase angle ( $r = -0.42$ ,  $P = 0.003$ ) were inversely correlated with age. Correlations of prealbumin with reactance and phase angle are graphically shown in Figures 1 and 2. We performed step-wise regression analysis to examine which of the nutritional markers, including age, were independent predictors of BIA parameters. For reactance, significant predictors were albumin ( $P = 0.006$ ), body weight ( $P = 0.031$ ), and prealbumin ( $P = 0.037$ ). For phase angle, significant predictors were serum albumin ( $P < 0.0001$ ) and BCM ( $P = 0.01$ ).

### Survival

During the study period, eight (17%) patients died. We stratified the patients by phase angle. On more than two years of observation, cumulative survival of PD patients with phase angle less than 6 degrees was significantly lower than those patients with phase angle equal to or greater than 6 degrees ( $P = 0.008$ ) (Fig. 3). Similar results were obtained after adjusting for age, race, gender, and diabetic status (Cox regression model). By univariate Cox regression analysis, both reactance (RR = 0.95,  $P = 0.031$ ) and phase angle (RR = 0.46,  $P = 0.014$ ) were significant predictors of mortality. In multivariate Cox regression analysis, after adjusting for age, race, gender, months on dialysis, and diabetic status, phase angle was an independent predictor of mortality (RR = 0.39,  $P = 0.027$ ) in PD patients. Phase angle was the only significant predictor in this model. Reactance was not a significant predictor of mortality in the Cox multivariate regression model.

## DISCUSSION

One of the most important observations in this study is that serum prealbumin, a highly sensitive marker of nutritional status, is strongly correlated with BIA parameters, impedance, and phase angle in PD patients. As expected, reactance and phase angle were also correlated with other serum nutritional markers. Resistance reflects the anthropometric characteristics of the patients, which is in agreement with previously published results [17]. The results of this study confirm the relationship between serum nutritional markers and BIA parameters in PD patients as we and others reported in previously published papers [8, 10, 18, 19]. To our knowledge, there is no information available in the literature regarding the relationship between prealbumin and BIA parameters in PD patients. Chertow et al [20] reported direct correlations of prealbumin with phase angle and reactance in

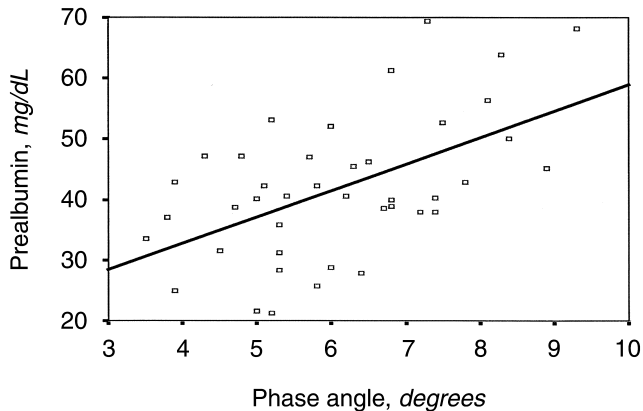
**Table 1.** Correlation coefficients of age and nutritional markers with BIA parameters ( $N = 48$ ) in PD patients

Variables	Age	Body weight	BMI	BCM	Prealbumin	Albumin	Creatinine	BUN
Resistance	-0.03	-0.58 <sup>b</sup>	-0.39 <sup>a</sup>	-0.61 <sup>a</sup>	0.29	0.21	-0.19	-0.19
Reactance	-0.37 <sup>a</sup>	-0.23	-0.14	-0.031	0.55 <sup>b</sup>	0.55 <sup>a</sup>	0.038	0.27
Phase angle	-0.42 <sup>a</sup>	0.14	0.12	0.41 <sup>a</sup>	0.54 <sup>b</sup>	0.54 <sup>b</sup>	0.15	0.46 <sup>a</sup>

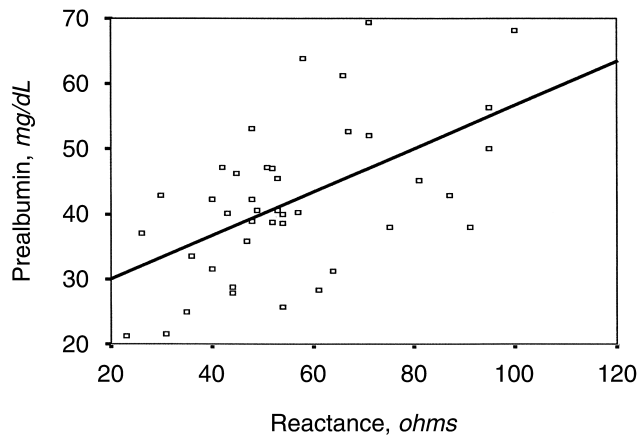
Abbreviations are: BIA, bioelectrical impedance analysis; PD, peritoneal dialysis; BMI, body mass index; BCM, body cell mass; BUN, blood urea nitrogen.

<sup>a</sup> $P < 0.01$

<sup>b</sup> $P < 0.0001$



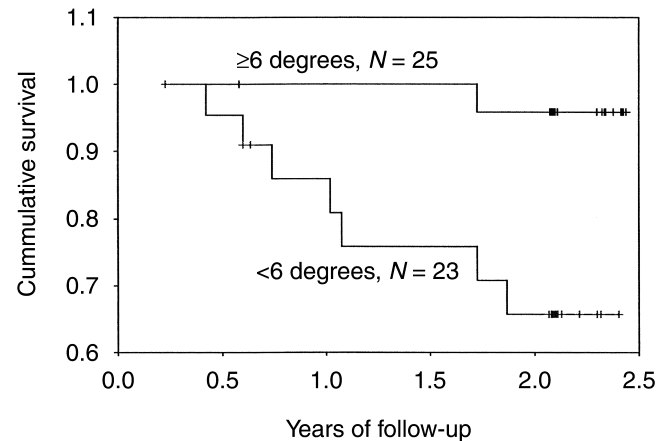
**Fig. 1.** Relationship between phase angle and prealbumin in 48 peritoneal dialysis (PD) patients ( $r = 0.54$ ,  $P < 0.0001$ ).



**Fig. 2.** Relationship between reactance and prealbumin in 48 peritoneal dialysis (PD) patients ( $r = 0.55$ ,  $P < 0.0001$ ).

HD patients, which were weaker than that in the present study.

It is well established that several nutritional parameters are significantly associated with survival in PD patients [14]. We examined the prognostic power of BIA parameters in PD patients. By Cox multivariate regression analysis, we have shown that phase angle is an independent predictor of more than two years' survival in PD patients. Maggiore et al [17] previously reported that phase angle is an independent predictor of survival in



**Fig. 3.** Kaplan-Meier estimates of observed survival during follow-up with regard to all cause mortality in peritoneal dialysis (PD) patients stratified by enrollment phase angle.  $P = 0.008$ .

HD patients. In the present study, reactance was not a significant predictor of mortality in Cox multivariate model, indicating the superiority of phase angle among BIA parameters as a prognosticator in PD patients. The phase angle has been reported as a more powerful predictor of survival than the usual nutritional indexes in HIV and HD patients [21, 22]. Phase angle is the arc tangent of the reactance to resistance ratio and reflects the relative contribution of reactance and resistance. Phase angle may reflect the derangement in the electrical charge in the cell membrane [21]. Recently, it has been reported that phase angle correlates with the fatty acid composition and cholesterol in red cells. Phase angle may provide a noninvasive method for monitoring intervention aimed at altering the lipid composition of membranes [23]. So far, it is not clear physiologically what phase angle means. It is possible that phase angle may reflect some form of abnormalities that are not associated with nutritional status [21]. Reactance is an indicator of lean body mass. However, reactance reflects the functional capacity of somatic protein stores and is, therefore, a better marker of overall nutritional status than lean body mass [7]. More studies are needed to understand the exact biological meaning of BIA parameters and their abnormalities in various disease conditions.

## CONCLUSION

Phase angle is an independent predictor of more than two years' survival in PD patients. Phase angle is a better prognostic index of patient survival than reactance and some demographic and clinical parameters.

## ACKNOWLEDGMENTS

This work was supported in part by grants from the Kidney and Urology Foundation of America, and the Nephrology Foundation of Brooklyn.

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