Magnitude of body-cell-mass depletion and the timing of death from wasting in AIDS[1-3]

Donald P. Kotler, Anita R. Tierney, Jack Wang, and Richard N. Pierson, Jr.

ABSTRACT The impact of malnutrition on survival in AIDS was evaluated by examining the magnitude of body-cell-mass depletion as a function of time from death. Body cell mass was estimated as total body-potassium content and determined by whole-body counting. There was progressive depletion of body cell mass as patients neared death. The extrapolated and observed values for body cell mass at death were 54% of normal. Body weight had a similar relationship to death, with a projected body weight at death of 66% of ideal. We conclude that death from wasting in AIDS is related to the magnitude of tissue depletion and is independent of the underlying cause of wasting. The degree of wasting seen in this study is similar to historical reports of semi-starvation, with or without associated infections. This observation suggests that successful attempts to maintain body mass could prolong survival in patients with AIDS . . . . . *Am J Clin Nutr 1989:50:444-7.*

Nutritional Assessment With Bioelectrical Impedance Analysis in Maintenance Hemodialysis Patients [1,2]

Glenn M. Chertow,[3] *Edmund G. Lowrie, Douglas W. Wilmore, Jorge Gonzalez, Nancy L. Lew, Jie Ling, Meryl S. Beboff, Michael N. Gottlieb, Wei Huang, Barbara Zebrowski, Joyce College, and J. Michael Lazarus*

ABSTRACT Protein energy malnutrition is common among persons with ESRD and contributes substantially to morbidity and mortality. The usual methods of nutritional assessments, such as anthropometry, can be misleading because of altered tissue hydration. Bioelectrical impedance analysis (BIA) has been recommended by some as a practical nutritional assessment tool but has not been validated in patients with ESRD. Thirty three stable patients on maintenance hemodialysis were evaluated in an ambulatory clinical research center with simultaneous BIA, dual-energy x-ray absorptiometry, and deuterium oxide (D_2O) and sodium bromide (NaBr) isotope dilution studies. Standard determinations of total body water (TBW) and body cell mass (BCM) were obtained and compared with values estimated by BIA. Two separate outpatient BIA measurements were also obtained approximately 2 wk before and after the clinical research center evaluation. BCM estimated by BIA was directly correlated ($r = 0.92$, $P < 0.00001$) with BCM determined by DEXA and NaBr. TBW estimated by BIA was directly correlated ($r = 0.96$, $P < 0.0001$) with TBW determined by deuterium oxide dilution. The reactance to resistance ratio (Xc/R) derived from BIA was inversely correlated ($r = -0.73$, $P < 0.0001$) with the extra-cellular water / TBW ratio determined by $NaBr/D_2O$. Bland-Altman analyses showed that for

TBW, BIA was in excellent agreement with D_2O dilution. BCM was modestly underestimated by BIA compared with the dual-energy x-ray absorptiometry/NaBr standard and was adjusted by linear regression. The coefficients of variation on repeated BIA measurements were below 4%, demonstrating test-retest reliability. BIA is a valid and reliable method of nutritional assessment in maintenance hemodialysis patients. . . . . *(J. Am. Soc. Nephrol. 1995; 6:75-81)*

Bioelectrical Impedance Analysis as a Predictor of Survival in Patients with Human Immunodeficiency Virus Infection

*Michael Ott, Harald Fischer, Hatice Polat, *Eike Brigitte Helm, Marcus Frenz, Wolfgang F. Caspary, and Bernhard Lemboke*

SUMMARY In patients with AIDS, short-term survival has been related to body weight, body composition, and serum nutritional parameters, but their prognostic impact at earlier stages of the HIV infection is not known. With an individual follow-up period of 1,000 days, we investigated the prognostic relevance of electrical tissue conductivity {resistance R, reactance Xc, phase angle a, extracellular mass (ECM), body cell mass (BCM) measured by bioelectrical impedance analysis, of the $CD4^+$ cell amount, and of serum parameters indicating malnutrition in 75 HIV-infected male patients at Walter Reed stages 3-5. After initial recording, 29 patients (38.7%) died from AIDS during this period. Among 12 parameters estimated with a semi-parametric Cox regression model adjusted for therapy (pentamidine, azidothymidine), the phase angle a (parameter estimate: - 1.043, 95% confidence interval of –0.61 to –1.47;$p < 0.00001$), the ECM/BCM ratio, Xc, BCM, serum cholesterol, number of $CD4^+$ cells, and serum albumin had significant prognostic influence on survival, whereas age, body weight, body mass index, resistance, serum protein and serum triglycerides did not. In a model with four covariates (CD_4^+ cells, phase angle, pentamidine, azidothymidine), the prognostic impact of the CD_4^+ cell count (parameter estimate: -0.549) was lower compared with the phase angle a (parameter estimate: -0.799; $p < 0.00001$) and did not gain statistical significance ($p = 0.0626$). The phase angle *a* was the best single predictive factor for survival among all 12 parameters (comparison of the respective Cox models with the likelihood ratio test). Body composition as reflected be the phase angle *a* is a major determinant of long-term survival in HIV infection, thereby representing an important parameter for monitoring disease progression. . . . .*Journal of Acquired Immune Deficiency Syndromes and Human Retrovirology 9-20-95, copyright 1995 Raven Press, Ltd. New York*

Incidence and Prognostic Value of Malnutrition and Wasting in Human Immunodeficiency Virus-Infected Outpatients

*Ulrich Suttmann, Johann Ockenga, *Oliver Selberg, Linda Hoogestraat, Helmuth Deicher, and Manfred James Muller*

SUMMARY Although malnutrition and wasting are known features of human immunodeficiency virus (HIV) infection, their incidence and possible association with immunologic impairment are largely unknown, as is the prognostic value of the nutritional state. Nutritional, clinical, and immunologic parameters were measured in 100 outpatients in different stages of HIV infection. In addition, 39 patients with AIDS were prospectively followed for a mean period of 343 (range. 53-560) days. Sixty three percent of the patients showed evidence of malnutrition, 21% suffered from wasting. A reduced body cell mass and decreased serum albumin levels were observed in 32 and 14%, respectively, predominately in more advanced disease stages. Fourteen of 39 AIDS patients died after a mean survival of 212 days. Survivors showed significantly larger initial body cell mass values and high initial serum albumin levels compared with non-survivors, whereas CD_4^+ lymphocyte counts, disease complications, and medication were all similar in both groups. Kaplan-Meier analysis revealed a significantly prolonged survival in patients with a body cell mass >30% of body weight or serum albumin levels exceeding 30 g/L. Factor analysis indicated that the parameters of nutritional state were independent from each other and from CD_4^+ lymphocyte counts. Malnutrition occurs frequently during HIV infection and increases with disease progress. It strongly predicts patient survival independent of CD_4^+ lymphocyte counts. . . . . . *Journal of Acquired Immune Deficiency Syndromes of Human Retrovirology, 3:239-246, copyright, 1995 Raven Press, Ltd. New York*

Body Fluid Overload and Bioelectrical Impedance Analysis in Renal Patients

Antonio Piccoli, Barbara Rossi, Luana Pillon, Giuseppe Bucciante

ABSTRACT Using a new bivariate vectorial approach to the standard bio-impedance analysis (tetrapolar, 50-kHz frequency), we evaluated the performance of a graphical method for the identification of patients with fluid overload. Two hundred and seventeen adult Caucasian subjects were divided into four classification groups: 86 healthy control subjects, 55 patients with mild-to-terminal chronic renal failure in conservative treatment (15% with apparent edema), 36 patients with idiopathic nephritic proteinuria (58% with apparent edema), and 40 obese subjects. We found a bio-impedance threshold for apparent edema on the lower pole of the sex-specific 75% tolerance ellipse (bivariate tolerance interval) of the healthy population. This innovative graphical method allows identification, monitoring and therapy planning of patients with fluid overload using direct bio-impedance measurements without any assumption of body composition . . . . . *Prof. A. Piccoli, InstituteMedical Intern., copyright, 1993, S. Karger AG, Basel 0378-0392*

Bioelectrical impedance assessment of nutritional status in critically ill patients [1,2]

Sylvie Robert, Barbara J. Zarowitz, Robert Hyzy, Michael Eichenhorn, Edward L. Peterson and John Popovich Jr.

ABSTRACT: The objective of this study was to assess the utility of bioelectrical impedance analysis (BIA) in determining nutritional status in critically ill patients in the intensive care unit (ICU). Data were collected prospectively in 33 mechanically ventilated medical and surgical ICU patients requiring nutrition as part of their care. BIA, was subsequent calculation of body composition indexes, was preformed every other day for the duration of ICU stay. Body cell mass (BCM) changes correlated with energy and protein intakes (r^2 0.87, $P < 0.001$ and $r^2 = 0.67$, $P < 0.001$, respectively). Maintenance of BCM was achieved by a daily provision of 125.5 kJ. $kg^{-1}.d^{-1}$ (30 kcal . $kg^{-1}.d^{-1}$) and 1.5 g protein/kg whereas greater intakes allowed restoration of BCM. The mean ratios of exchangeable sodium to potassium (Na_e:K_e) improved only in patients achieving positive nitrogen balance ($P = 0.013$). Body-composition changes determined by BIA represent a feasible adjunctive method for evaluating and monitoring nutritional status in ICU patients. . . . . *Am J Clin Nutr 1993;57:840-4., printed in the USA*

Rapid bedside method to assess changes in postoperative fluid status with bioelectrical impedance analysis

Michael M. Meguid, MD, PhD, Henry C. Lukaksi, PhD, Mark D. Tripp, MD, Joel M. Rosenburg, MD and Frederick B. Parker, Jr., MD

BACKGROUND Estimates of daily postoperative fluid balance usually rely on properly recorded inputs, outputs, and daily weights or clinical signs. These may be imprecise (when poorly done) and are often considered tedious to perform.
METHODS We've used bioelectrical impedance analysis (BIA) to assess changes in body water shifts in cardiac after surgery. Nine consecutively admitted patients undergoing coronary artery bypass (seven men and two women; age range 43 to 67 years) were studied. Body weight, fluid intake and output, and BIA variable (resistance and reactance) were measured daily. Relationships between body weight and changes in resistance and reactance and net change in fluid balance (in liters per day) were evaluated statistically by regression analysis.
RESULTS Mean body weights changed significantly reflecting early operative fluid accumulation and later postoperative diuresis; net fluid balance correlated poorly ($r = 0.48$; $p < 0.05$) with body weight, whereas both resistance ($r = -0.82$; $p < 0.001$ and reactance ($r = -0.92$; $p < 0.0001$) correlated highly with net fluid balance.
CONCLUSIONS BIA is useful as an accurate, rapid bedside method for assessing changes in hydration status sequentially after surgery in cardiac patients with complicated fluid shifts. . . . . *Surgery 1992;112:502-8.*

Perioperative monitoring of total body water by bio-electrical impedance in children undergoing open heart surgery

T. Maehara, I. Novak, R.K.H> Wyse, and M.J. Elliot

ABSTRACT Knowledge of the changes in total body water (TBW) following cardiac surgery (OHS) in children would be of value in fluid therapy and in researching the causes and management of capillary leak. We have validated a bioelectrical impedance technique (BEI) for non-invasive estimation of TWB in children after OHS. We report the use of this method in a longitudinal study. Twenty patients (mean age 4.7 years ± 3.5 SD), mean weight (WT) 16.2 kg ± 1 kg) undergoing a variety of complex OHS procedures were studied from 1 day preoperatively to 4 days postoperatively. Anesthetic and basis bypass (CPB) techniques were uniform. Six patients underwent CPB at less that 20°C, 10 at 20° - 25°C and 4 at 26° – 33°C. TBW (BEI), core (ctemp) and peripheral (ptemp) temperatures and fluid balance (TFB) were recorded at frequent intervals. TBW (by BEI) rose ($P<0.001$) following CPB in all patients from 62% ± 9% (SD) body weight preoperatively to 73% ± 13% in the ICU (an increase of 11% ± 5%). TBW remained significantly elevated until the 3rd postoperative day. Multivariate analysis (MVA) confirmed that TBW was significantly related to TFB, but not to ctemp or ptemp. MVA also revealed smaller patient size (height and weight), younger age and longer CPB time as incremental risk factors for the rise in TBW. Conclusions: (1) BEI permits the non-invasive study of TBW

in children after OHS, when TBW variation may be considerable. (2) The smaller the child and the longer the CPB, the greater the rise in TBW. (3) The technique should be a valuable tool in researching the major water fluxes associated with CPB in children. . . . . *Eur J Cardio-thorac Surg (1991) 5:258-265)*

Is the impedance index (ht^2/R) significant in predicting total body water? [1-3]

Robert F Kushmer, Dale A. Schoeller, Carla R. Fjeld, and Lynn Danford

ABSTRACT We investigated the general utility of bioelectrical impedance analysis (BIA) and the implications of BIA theory in populations of various ages from infancy to adulthood by developing a single impedance equation. Four subject data sets representing 62 adults, 37 pre-pubertal children, 44 preschool children, and 32 premature low-birth weight neonates were combined. Subjects were randomly divided into a development group (n = 116) and a cross-validation group (n = 59). The single best predictor of total body water (TBW) was height^2/resistance (ht^2/R). which explained 99% of the variation in TBW (SEE = 1.67 kg). The addition of weight reduced the SEE to 1.41 kg. A significant bias was only seen in the preschool children. These results were confirmed in the cross-validation group and the best prediction formula as TBW = 0.59 ht^2/R + 0.065 wt + 0.04. We conclude that the impedance index (ht^2/R) is a significant predictor of TBW and that there is some improvement in prediction of TBW by inclusion of a weight term. . . . *Am J. Clin Nutr, 1992;56:835-9.*

Estimation of Body Fluid Volumes Using Tetrapolar Bioelectrical Impedance Measurements

Henry C. Lukaski, Ph.D., and William W. Bolonchuk, M.Sc.

Mathematical equations using tetrapolar bioelectrical resistive (R) and reactive (Xc) impedance measures were developed and cross validated to predict total body water (TBW) and corrected bromide space (CBS) in two independent samples (n = 110). Height^2 per low R was the best predictor of TBW (R = 0.96) and CBS (R = 0.92). When the influence of TBW was removed from CBS and dependant variables, height^2 per low Xc was the best predictor (R = 0.50) of CBS. Double cross validation of each sample showed that observed and predicted TBW (R = 0.978 and 9.986) and CBS (0.937 and 0.907) were significantly related ($p<0.001$), and there was no difference ($p>0.05$) between the values. The lines representing the relationships between observed and predicted values had regression coefficients not different than the line of identity. Data from both samples were combined to give a representative multiple regression equation to predict TBW and CBS. This

study establishes the validity of the tetrapolar bioelectrical impedance method to assess body fluid volumes in humans. . . *Aviat. Space Environ. Med., 1988; 59:1163-9*

Body Composition in Patients With Acquired Immunodeficiency Syndrome: A Validation Study of Bioelectrical Impedance Analysis

T.E.M.S. Sluys, MSC; M.E. Van Der Ende, MD; G.R. Swart, MD; J.W.O. Van Den Berg, PhD; and J.H.P. Wilson, MD

ABSTRACT The objective of this validation study was to explore bioelectrical impedance analysis (BIA) as a way to assess nutritional status and body composition. The study was done in the outpatient department of the AIDS unit at University Hospital Dijkzigt, Rotterdam, The Netherlands. Eleven clinically stable patients with AIDS were studied. Total body water, body fat, lean body mass, and body cell mass were measured and calculated with multiple dilution techniques and BIA. With linear regression analysis, a strong correlation was found between total body water and lean body mass derived from BIA and multiple dilution techniques (r^2= .96 and .98, respectively), and slightly weaker correlation was found for body cell mass and body fat (r^2= .88 and .76, respectively). These results suggest that BIA is a suitable method for the assessment of body cell mass in HIV-infected patients without opportunistic infections. The technique is safe, non-invasive, fast, and inexpensive. . . . *Journal of Parenteral and Enteral Nutrition 17:404-406, 1993*

Bio-impedance monitoring of re-hydration in cholera

J.J. McDonald, B. Chanduvt, G. Velarde, R. Cama, F. Diaz, L. Carrillo, V. Torre, J. Watanabe, J. Villarreal, A. Ramirez-Ramos, R. Mantle, and R.H. Gilman

Measurement of bio-impedance (BI) is a simple non-invasive technique that relies on the different conductivity of tissues to define body composition and can be easily adapted to automated monitoring. We assessed the accuracy of BI in monitoring re-hydration and acute fluid fluxes in 35 Peruvian cholera patients. Patients were monitored throughout the acute phase of diarrhea and followed up at 3 and 10 days. BI was compared with other objective measures of dehydration including packed cell volume, serum protein, and calculated fluid balance. BI rapidly detected inadequate treatment and acute fluid flux, correlating highly with intra-vascular hydration as measured by serum protein and packed cell volume. BI values during dehydration were significantly raised compared with 10-day convalescent values and age-matched controls ($p<0.05$). We also encountered an unexpected difference in the bioelectrical response to dehydration and re-hydration between sexes. We

conclude that BI has uses in monitoring dehydrated patients, in oral re-hydration trials, and in physiological studies. . . . *Lancet, 1993; 341 1049-51.*

A Comparison of Fat-free Mass Estimates in Men Infected With the Human Immunodeficiency Virus

J.M.H. Risser, PhD, L. Rabeneck, MD, MPH*, L. W. Foote, RN*, And W.J. Klish, MD*

ABSTRACT *Background:* Loss of lean-body mass has been found to be predictive of death from wasting in HIV-infected individuals. Several clinically applicable, noninvasive methods for estimating body wasting are available, but the comparability of these methods is not known. The objective of this study was to assess the agreement between estimates of lean-body mass in HIV-infected men. *Methods*: Lean-body mass was measured by bioelectrical impedance assessment, by prediction equations that used anthropometric measurements, and by total body electrical conductivity as the comparison method in 27 outpatient HIV-infected men seen at the Houston Veterans Affairs Special Medicine Clinic. Agreement was assessed by comparing the difference between two methods (the bias) with the mean of those two methods. This statistical approach evaluates whether two methods are similar enough that measurements from one might accurately replace those of the other. *Results:* The mean ± SE for the lean-body mass were 55.98 ± 1.96 kg for total body electrical conductivity and 55.18 ± 1.27 kg for bioelectrical impedance assessment; they ranged from 55.18 ± 1.27 to 63.71 ± 1.89 kg for the prediction equations. *Conclusions:* In individual subjects, no alternate method gave estimates of lean-body mass that were the same as estimates from total body electrical conductivity. One prediction (Brozek) gave estimates that might be useful for following changes in fat-free mass over time because the bias did not change substantially for increasing values of lean-body mass. On the other hand, because there were no statistically significant differences between the mean lean-body mass estimates by total body electrical conductivity and those measured by bioelectrical impedance assessment of a prediction equation of the basis of body mass index, the latter two methods might be useful in assessing lean-body mass in groups. . . . *Journal of Parenteral and Enteral Nutrition 19:28-32, 1995*

Body composition by bioelectrical-impedance analysis compared with deuterium dilution and skin fold anthropometry in patients with chronic obstructive pulmonary disease[1,2]

Annemie MWJ Schols, Emiel FM Wounters, Peter B. Soeters, and Klaas R. Westerterp

ABSTRACT Body composition is an important measure of nutritional status in patients with chronic obstructive pulmonary disease (COPD). We generated a regression model for bioelectrical impedance (BI) by using deuterium dilution (^2H_2O) as a reference method in 32 COPD patients, aged 63 ± 9 y ($\chi \pm$ SD), in stable pulmonary and cardiac condition. Height squared divided by resistance (Ht^2/Res) correlated well with total body water (TWB) as measured by ^2H_2O ($r = 0.93$ $P < 0.001$, SEE = 1.9 L). The best fitting regression equation to predict TBW comprised Ht^2/Res and body weight ($r^2 = 0.89$, SEE = 1.8 L, $P < 0.001$). BI predicted TBW was used to eliminate BI-fat-free mass (FFM) that was compared with skin fold-thickness-based FFM predictions (Anthr-FFM). Relative to BI-FFM a significant overestimation of 4.4 ± 0.8 kg was found by Anthr-FFM. Our results suggest that BI is a useful measure of body composition in patients with severe COPD. . . . *Am J Clin Nutr 1991;53:421-4.*

Electrical impedance in assessing human body composition: the BIA method [1-3]

M. Abu Khaled, PhD; Martin J. McCutcheon, PhD; Srikar Reddy, BS; Paul L. Pearman, MA; Gary R. Hunter, PhD; and Roland L. Weinsier, MD

ABSTRACT Fundamental aspects of the body impedance analysis (BIA) method were investigated to determine limitations. This method measures body impedance with a low-level (800 πA) 50-KHz current conducted through the tissues. A linear regression equation was proposed to relate impedance measurements to total body fat. The hydrostatic densitometric method (underwater weighing) was used to validate the proposed mathematical expression. A correlation coefficient of 0.98 between these two methods was obtained. The overall results from this study indicate the usefulness of the BIA method in determining percent body fat in humans provided body fluids are not perturbed several hours before the measurements. . . . *Am J Clin Nutr 1998;47:789-92.*

The Predictive Role of Bioelectrical Impedance Analysis (BIA) in Postoperative Complications of Cancer Patients:

Fritz; Hollwatth, I; Romaschow M; Schlag P.

ABSTRACT The correlation between body composition measured by bioelectrical impedance (BIA) and postoperative complications in 115 patients with gastrointestinal cancer was analyzed. A significant increase in server complications was found independent of lean body mass (LBM). In patients with LBM below normal range the complication rate proved to be 31% (17/55), whereas patients with normal LBM had a complication rate of 10% (6/60). Other decisive factors, such as sex, age, tumor stage, operative procedure and body height were equally distributed in both groups. The

practicability and efficiency of BIA became obvious in this study. . . . . *Dept. of Surgery, University of Heidelberg*

Bio-impedance Analysis (BIA) in the Assessment of Nutritional Status of Dialysis Patients

Q. Maggiore, S. Nigrelli, G. Enia, C. Circcarelli, Rossi, Santoni, T. Cerrai

ABSTRACT The assess whether BIA yields reliable information for evaluating the nutritional status in hemodialysis populations we compared the BIA results with anthropometric measurements (MAMC), urea appearance rate (UAR), serum albumin and subjective global assessment (SGA) obtained concurrently in 108 patients on Renal Dialysis Treatment. Among the data provided by BIA we chose the Body Cell Mass (BCM), as estimate based on height/resistance factored by the phase angle, because in a preliminary study on 25 patients it showed the best correlation with urea distribution volume (.92) and creatinine appearance rate (.89), both calculated from total serum dialysate for 6 consecutive dialysis sessions. BCM correlated significantly ($p<.01$) with serum albimin (r=.37), MAMC (r=.56), URA (r=.56) and appeared to be the best predictor of the SGA score. Taking the 10^{th} percentile of the healthy populations the cut-off point, ie.; 23.7 Kg for male and 17.2 Kg for female (values derived from 238 healthy subjects) BCM detected 17 of 21 grade two patients (moderately malnourished and 10 of 10 grade three patients (severely malnourished) in the SGA score, with an overall sensitivity of 96%. The data suggest that BIA is a useful tool for evaluating the nutritional status of dialysis patients.

Early changes of body composition in human immunodeficiency virus-infected patients: tetra-polar body impedance analysis indicates significant malnutrition [1-3]

Michael Ott, Bernhard Lembcke, Harald Fischer, Regina Jager, Hatice Polat, Helmut Geier, Monika Rech, Schlomo Staszeswki, Eike Brigitte Helm, and Wolfgang F. Caspary

ABSTRACT Total body water, body fat, body cell mass (BCM), extra-cellular mass (EMC), and the EMC-BCM ratio by impedance analysis were determined in 193 human immunodeficiency virus (HIV)-infected patients and 340 control subjects. Walter Reed (WR) classification was WR 2 in 26. WR 3-5 in 85, and WR 6 in 82 patients. Whereas resistance was increased, reactance and the phase angle were significantly reduced in all patient groups. Neither body weight nor body mass index (BMI) was affected in WR 2 patients, but BCM was reduced (31.9 ± 4.3 vs 35.8 ± 7.3 kg, $P < 0.007$) and ECM (31.2 ± 4.4 vs 28.8 ± 3.8 kg) as well as ECM-BCM ratio increased (0.99 ± 0.14 vs 0.83 ± 0.16, $P < 0.001$). In contrast to WR classification, diarrhea

did not correspond with malnutrition. A loss of BCM (malnutrition) occurred already in otherwise symptom less HIV-infected patients (WR 2). This effect can be measured by tetra-polar impedance analysis but not by body weight of BMI. . . . . *Am J Clin Nutr 1993;57:15-9.*

Accuracy of Bioelectrical Impedance Analysis in Estimation of Extra-Cellular Space in Healthy Subjects and in Fluid Retention States

Giuseppe Sergi, Mauro Bussolotto, Paola Perini, Irene Calliari, Valter Giantin, Anna Ceccon, Flavio Scanferla, Marta Bressan, Giuliano Moschini, Giuliano Enzi

ABSTRACT Bioelectrical impedance analysis (BIA) is a noninvasive method recently introduced for body fluid evaluation in healthy subjects. The purpose of this paper is to verify the reliability of bioelectrical measurements in extra-cellular water (ECW) prediction in healthy subjects and in fluid retention states. We studied 40 subjects (19 males and 21 females) aged 21-81 years; 22 were healthy subjects, 12 were affected by chronic heart failure, and 6 by chronic renal failure. In all subjects resistance (R) and reactance (Xc) at 1 and 50 kHz corrected for height were compared with ECW measured by the bromide dilution method. Our results suggested a different behavior of the current in fluid-retention states with respect to healthy subjects. ECW was best predicted by resistance at 1 kHz corrected for height, group (considered as dummy variable), weight and gender ($R^2 = 0.89$, $p < 0.001$, SEE = 1.7 liters). The bioelectrical impedance analysis at 50 kHz explained the 89% of ECW variability when resistance and reactance corrected for height are considered with gender group and weight ($R^2 = 0.89$, $p<0.001$, SEE = 1.7 liters). In conclusion, the bioelectrical method at 1 kHz can be considered sufficiently accurate in ECW prediction in healthy subjects and in fluid retention states. Also, the bioelectrical impedance analysis at 50 kHz is useful for predicting ECW, but his role must be further investigated. . .
Ann Nutr Metab 1994;38:158-165

Total body water in pregnancy: assessment by using bioelectrical impedance [1-3]

Henry C. Lukaski, William A. Siders, Emily J. Nielsen, and Clinton B. Hall

ABSTRACT Determinations of total body water (TBW) calculated from deuterium dilution spaces and bioelectrical-impedance measurements were made serially in a group of 15 women before, during, and after pregnancy. Similar measurements were made once in a group of 50 non-pregnant women and intermittently in another group of 10 women during pregnancy and postpartum. TBW increased significantly during pregnancy, then decreased postpartum. Estimates of TBW in pregnancy and postpartum calculated with models derived from non-pregnant and pregnant women were similar to

measured values. Changes in reactance and resistance explained more of the variance in predicting changes in TBW than did body weight, abdominal circumference, or hematocrit (50-75% vs 4-50%, respectively). Changes in TBW estimated with the non-pregnancy impedance model were significantly different than either the measured changes or changes predicted with the pregnancy impedance model. These findings indicate that the impedance method is a practical and valid method for determining longitudinal changes in TBW. . . . . *Am J Clin Nutr 1994;59:578-85.*

Early Changes of Body Composition in Human Immunodeficiency Virus-Infected Patients: Tetra-polar Body Impedance Analysis Indicates Significant Malnutrition

M. Ott, B. Lembcke, H. Fischer, ET AL

ABSTRACT In this study the investigators examined alterations in body composition and the prevalence of diarrhea in HIV-infected subjects. By using tetra-polar body impedance analysis (RJL-Akern BIA 109:Data-input, Frankfurt/Main, Germany), body composition was measured in 533 subjects, including 193 men ages 21 to 70 years, who had tested positive for HIV /1 antibodies and 340 age and sex-matched control subjects. HIV-infected patients were grouped according to the Walter Reed (WR) classification of HIV disease stages.[1] Total body water, extra-cellular mass (ECM), body fat body cell mass (BCM), and ECM/BCM ratio were determined. Relative to control subjects, the body weight and body mass index (BMI) of WR 3 through WR 5 (n = 85) and WR 6 (n = 83) subjects were significantly decreased ($p < .29$ and $p < .001$, respectively), whereas WR 2 (n = 26) subjects exhibited no decline in either body weight or BMI. However, all HIV-infected subjects including those classified as WR 2, displayed both a statistically significant decline in BCM and an increase in ECM, resulting in an increased ECM/BCM ratio. The use of tetra-polar impedance detected depletion of lean body mass in clinically a symptomatic HIV patients at the WR 2 stage who had not yet demonstrated alterations in body weight or BMI. Malnutrition can be defined as a state of decreased BCM and increased ECM. The altered ECM/BCM ratio is independent of body weight or BMI. Almost half the WR 2 patients had ECM/BCM ratios greater that those of matched control patients by 1 standard deviation. No significant depletion of fat stores was noted in any group except in the most severe WR 6 patients. When patients were classified into four diarrheal states in terms of stool evacuation, consistency, duration, and frequency, only the most severe state (patients with either more than 20 diarrheal episodes of more than 3 days duration or permanent diarrhea during the last year) correlated with the degree of malnutrition. . . . *American Journal of Clinical Nutrition 57:15-19, 1993*

Assessment of fat-free mass using bioelectrical impedance measurements of the human body [1,2]

Henry C Lukaski, PhD, Phyllis E Johnson, PhD, William W Bolochuk, MSc, and Glenn I Lykken, PhD

ABSTRACT A method which involves the measurement of bioelectrical resistive impedance (R) for the estimation of human body composition is described. This method is based upon the principle that the electrical conductivity of the fat-free tissue mass (FFM) is far greater than that of fat. Determinations of R were made in 37 healthy men ages 28.8 ± 7.1 (mean ± SD) using an electrical impedance plethysmograph with a four electrode arrangement that introduces a painless signal (800 πA at 50 kHz) into the body. FFM was assessed by hydrodensitometry and ranged from 44.6-98.1 kg. Total body water (TBW) determined by D_2O dilution and total body potassium (TBK) from whole body counting were 50.6 ± 10.3 L and 167.5 ± 38.1 g, respectively. Test-retest correlation coefficient was 0.99 for a single R measurement and the reliability coefficient for a single R measurement over 5 days was 0.99. Linear relationships were found between R values and FFM ($r = -0.86$), TBW ($r = -0.86$, and TBK ($r = -0.79$). Significant ($p < 0.01$) increases in the correlation coefficients were observed when the predictor Ht^2/R was regressed against FFM ($r = 0.98$), TBW ($r = 0.95$)m and TBK ($r = 0.96$). These data indicate that the bioelectrical impedance technique is a reliable and valid approach for the estimation of human body composition. This method is safe, noninvasive, provides rapid measurements, requires little operator skill and subject cooperation, and is portable. Further validation of this method is recommended in subjects with abnormal body composition.
Am J Clin Nutr 1985;41:810-817.

Bioelectrical Impedance in Clinical Practice

Barbara J. Zarowitz and Alison M. Pilla

ABSTRACT Bioelectrical impedance (BI) relies on the conduction of a low-voltage alternating current through the body. Lean tissue and fluids containing electrolytes conduct the current and cell membranes serve as capacitors and account for capacitive resistance. Fat and bone are poor conductors. Measurement of the voltage drop of the applied current yields resistance (R) and reactance (X_c). R and X_c are used with height, weight, age and gender in a number of multiple regression relationships to predict body composition compartments such as fat-free mass, lean body mass, extra-cellular mass, and body cell mass. The technique has been compared with and validated against traditional measures of body composition analysis. In clinical practice, BI has been used to monitor fluid status in burn and dialysis patients, assess changes of body cell mass with nutritional repletion, and predict pharmacokinetic parameters and dose of theophylline and aminoglycoside antibiotics. BI is a noninvasive, safe, rapid, and reproducible technique with exciting potential in clinical practice. . . . *DICP 1989;23:548-55.*

Validation of bioelectrical-impedance analysis as a measurement of change in body composition in obesity [1,2]

Robert F Kushner, Annette Kunigk, Michael Alspaugh, Paul T Andronis, Catherine A Leitch, and Dale A Schoeller

ABSTRACT The bioelectrical-impedance-analysis (BIA) method accurately measures body composition in weight-stable subjects. This study validates the use of BIA to measure change in body composition. Twelve obese females underwent weight loss at a mean rate of 1.16 kg/wk. Body composition was measured by deuterium oxide dilution (D_2O), BIA, and skin fold anthropometry (SFA) at baseline and at 5% decrements in weight. Highly significant correlations were obtained between D_2O and SFA ($r = 0.932$). Overall, BIA predicted change in fat-free mass with greater accuracy (to 0.4 kg) and precision (±1.28 kg) than did anthropometry (to 0.8 kg and ± 2.58 kg, respectively). We conclude that BIA is a useful clinical method for measuring change in body composition. . . . *Am J Clin Nutr 1990;52:219-23.*

Methods for the assessment of human body composition: traditional and new[1-3]

Henry C. Lukaski, PhD

ABSTRACT Renewed interest in the assessment of human body composition has stimulated the need for a balanced understanding of available methodologies of estimating fat-free mass and percent body fat. This review summarizes the physical bases and assumptions, describes applications, and discusses the theoretical and practical limitations of currently available indirect methods. Although standard methods are discussed, recent modifications and adaptations are emphasized. . . . *Am J Clin Nutr 1987;46:537-56*

Estimation of Body Fluid Volumes Using Tetrapolar Bioelectrical Impedance Measurements

Henry C. Lukaski, Ph.D, and William W. Bolonchuk, M.Sc.

Mathematical equations using tetra-polar bioelectrical resistive (R) and reactive (X_c) impedance measures were developed and cross-validated to predict total body water (TBW) and corrected bromide space (CBS) in two independent samples ($n = 110$.) Height ^{2} per low R was the best predictor of TBW ($R = 0.96$) and CBS ($R = 0.92$). When the influence of TBW was removed from CBS and dependant variables, height^2 per low X_c was the best predictor ($R = 0.50$) of CBS. Double cross-validation of each sample showed that observed and predicted TBW ($R = 0.978$ and 9.986) and CBS (0.937 and

0.907) were significantly related (p 0.001), and there was no difference)p 0.05) between the values. The lines representing the relationships between observed and predicted values had regression coefficients not different than the line of identity. Data from both samples were combined to give a representative multiple regression equation to predict TBW and CBS. This study establishes the validity of the tetra-polar bioelectrical impedance method to assess body fluid volumes in humans. . . .. *Aviat. Space Environ. Med. 1988;59:1163-9*

Determination of Upper Arm Muscle and Fat Areas Using Electrical Impedance Measurements

B.H. Brown, T. Karatzas, R. Nakielny and R.G. Clarke

An electrical impedance technique is described which enables the cross-sectional areas of fat and muscle in the upper arm to be recorded. By making comparisons with measurements obtained using the x-ray technique of computerized tomography (CT) scanning it is shown that fat can be determined to a mean accuracy of 2.3 cm and muscle to a mean accuracy of 1.5 mm. These are more accurate than a parallel set of measurements made using the traditional technique. . . . *Dep. Of Medical Physics and Clinical Engineering, Royal Hailamshire Hospital, Sheffield, S10 2JF, UK, Received 1 April, 1987, in final form 21 August 1987.*

Body composition in Pima Indians: validation of bioelectrical resistance [1,2]

Russell Rising, Boyd Swinburn, Karen Larson, and Eric Ravussin

ABSTRACT To assess the validity of bioelectrical resistance (BR) in an obese population, body composition was determined to both hydrostatic weighing and by BR in 156 Pima Indian volunteers representing a wide range of body weight (46.1 – 202.6 kg) and body composition (11 – 52% fat). A predictive equation was derived by use of data on height, BR, weight, age, and sex from 130 randomly selected volunteers and was applied to the remaining 26 volunteers. When compared with the manufacturer's software, the new equation increased correlations with hydrostatic weighing for predicting percent body fat and fat-free mass (FFM) from 0.70 to 0.92 and 0.79 to 0.97, respectively. The manufacturer's software underestimated FFM by 5.3 ± 8.6 kg ($P < 0.05$) when compared with FFM derived from hydrostatic weighing whereas the new equation improved the accuracy to –0.1 ± 3.3 kg (NS). There were no significant effects of fluid intake (700 mL) or breakfast consumption on body composition as determined by BR. BR represents a simple and accurate way to assess body composition in Pima Indians with our newly derived equation. . . . . *Am J Clin Nutr 1991;53:594-8.*

Total Body Water in Congestive Heart Failure

R. Subramanyan, S.C. Manchanda, J. Nyboer, M.L. Bhatia

SUMMARY Total body bioelectric impedance technique was utilized in 50 patients with congestive heart failure (CHF) to determine total body water (TBW) before and after treatment. TBW was significantly higher in CHF as compared to normal matched controls, and the values decreased significantly after treatment. The reactance in patients with CHF was significantly altered suggesting a change in cell wall permeability, which was corrected after treatment. It is concluded that bioelectrical impedance offers a simple and a-traumatic technique to objectivity measure in TBW and guide the therapy in patients with CHF. . . . *Jr. Asso. Phys. Ind. Vol, 28, September 1980*

Resistance and Capacitance in Biological Conductivity

R. Liedtke, J. Nyboer, T. Talluri, M. Singer, and M. Hammond

ABSTRACT The accurate equivalent electrical model of a total body or regional impedance measurement will reveal the volume of fluids and tissues stored in extra-cellular and intra-cellular compartments. Mono frequency tetra-polar bio-electrical impedance analyzers measure resistance and reactance as vectors of impedance magnitude and accurately describe simple series or parallel electrically equivalent models. The complex electrical equivalent model can only be found with multiple frequencies spanning resistive and reactive vectors over three decades. However, the mathematical trans-
Formation of a single equivalent resistor and capacitor in parallel will yield a significant improvement in prediction equations that describe intra-cellular and extra-cellular compartments at 50 Khz. Intra-cellular volume is related to electrical capacitance (pico Farads) and extra-cellular volume is related to electrical resistance. Traditional prediction equations incorporate the instruments displayed resistance and reactance values as a series equivalent model. This, indeed, is not the case when the actual model is a parallel network or resistors and capacitors. Separating or removing the resistive and capacitive components inter-dependence as a parallel network is the purpose of this paper. In addition, instrument specifications and calibration standards have to be established for precise biological tissue measurements at any frequency from 1 Khz to 1 Mhz. . . . .Ó *copyright 1993, RJL Systems, Inc.*

612 VALIDITY OF HIR FOR ESTIMATION HUMAN BODY COMPOSITION

R.G. Isreal, FACSM; J.A. Houmard, K.F. O'Brien, M.R. McCammon, B.S. Zamora, and A.W. Eaton**

Near-infrared spectrophotometry (NIR) has recently been introduced for assessing body composition (MSSE 20(2):S8, 1998). The purpose of this study was to test the validity of an NIR device (Futrex 5000) by comparing it against hydrostatic weighing (HW) and 7 and 3 site skin folds. Subjects were 80 Caucasian males (x ± SD) (age, 26 ± 10.2 yrs). The NIR measurement was made in duplicate by placing the light wand on the anterior midline of the bicep halfway between the antecubital fossa and the acromion process of the right arm as specified by the manufacturer. The optical density detained was placed in the manufacturer's equation to predict & fat. Skin-fold measurements were made in duplicate on the right side using Harpenden calipers at the following sites: chest, axilla, sub-scapula, triceps, suprallium, abdomen, and thigh. Jackson and Pollack 7 and 3 site equations were used to predict body density. Body density was determined by HW, with residual volume determined in duplicate using oxygen dilution. All body densities were converted to % fat using the Sirl equation. Correlations between HW and other methods were as follows: NIR (r = .86). Mean values for % fat were: HW 12.8 ± 6.7, 7-site skin-folds 12.9 ± 6.1, 3-site skin-folds 12.2 ± significantly ($p < .05$) underestimated body fat when compared to other methods while HW and skin-fold methods were not significantly different. These results suggest the current NIR device using only the biceps measurement was not valid in population. Further research is warranted using multiple sites to elucidate the potential of NIR in body composition assessment. . . . *Vol. 21, No. 2 Supplement, Saturday, June 3*

ON-LINE BIOELECTRIC IMPEDANCE DURING HEMODIALYSIS: MONITORING OF BODY FLUIDS AND CELL MEMBRANE STATUS

F. Scanforla, S. Landini, A. Fracasso, P. Morachiello, R. Righetto, P.P. Toffoletto, and G. Bazzato

ABSTRACT We have measured by a computer integrated system (BIA-109 RJL/AKERN) the changes of bio-impedance (BI) deriving from a tetra-polar system working on 800 micro-amps @ 50KHz current in 23 hemodialysed patients. Resistance (R) and Reactance (XC) have been continuously monitored during hemodialysis in each patient. Resistance was strictly inversely correlated to the decrease of body weight (r = .82). Also XC increased almost constantly. In most of the patients the increase of XC was proportionately greater than R, resulting in an increase of phase angle (PA). However XC showed a transient decrease in response to seven severe symptomatic hypotensive episodes, whereas R maintained the increasing trend, causing a sharp reduction of phase angle. As XC is an expression of storage of electrical charge by the cells acting as condensers and phase angle quantifies the active capacitive component in relation to passive electrical resistance, these parameters may be important to evaluate cell membrane function. In fact, the univocal increase of R, XC and phase angle observed during normal uneventful hemodialysis probably indicates improvement of

cellular activities due to the depurative treatment. On the contrary, the transient reduction of XC and phase angle observed during hypotensive crisis may be an expression of cellular distress because of too rapid ultra-filtration. .
Nephrology & Dialysis Dept., Umberto Hospital, Venice, Italy. Nephrol Dial Transplant Suppl. 1 (1990) pp. 167-170.

ASSESSMENT OF REFIL AND HYPOVOLEMIABY CONINTUOUS SURVEILLANCE OF BLOOD VOLUME AND EXTRA-CELLULAR FLUID VOLUME

H.J. Gogaard, J.P.P.M. de Vries (*), P.M.J.M. de Vries

SUMMARY During renal replacement therapy hypovalaemia due to ultra-filtration (UF) may, when not sufficiently counteracted by refilling from the interstitium, result in hypotension. Combining two recently developed methods the haemodynamic process of refill was studied in order to find characteristics featuring hypotension. Blood volume (BV) and extra-cellular fluid volume (EFV) were measured continuously in 40 stable haemodialysis patients by means of an optical and a conductivity technique respectively. Regarding their post-dialytic (PD) EFV the patients were divided into three groups: non-hydrated (N, n=20), dehydrated (D, n=11) and over-hydrated (0, n=9). Significant differences between the groups were assessed in BV decrease (after 2 hours $p<0.05$ and after 3 hours $p<0.01$), EFV decrease (after 3 hours $p<0.05$ and occurrence of hypotensive episodes (N:5, D:7, 0:none, $p<0.01$). During the entire session the speed of BV decrease was significantly higher in hypotensive patients (H) than in non-hypotensive patients (non-H) and at the moment of hypotension (after 141+49 min), residual BV was less ($p<0.0005$) in H (87.7+5.17) than in non-H (96.5+4.0) at the corresponding moment. PD PV and PD EFV correlated in N ($r=0.52$, $p<0.025$), D ($r=0.81$, $p<0.005$) and H ($r=.071$, $p<0.01$.) UF-volume (differences between the groups were not significant) correlated to EFV decrease ($r=0.45$, $p<0.005$). In conclusion, the combination of both non-invasive methods elucidates the physiology of refill and pathophysiology of UF induced hypotension and provides a means of reducing dialysis morbidity. . . . *Departments of Internal Medicine and Medical Physics (*), Free University Hospital, Amsterdam, The Netherlands*

WHOLE BODY IMPEDANCE MEASUREMENTS REFLECT TOTAL BODY WATER CHANGES. A STUDY IN HEMODIALYSIS

Ljungqvist O. Hedenborg, G. Jacobson S.H. et al.

Fluid volume change during hemodialysis was monitored by continuous whole body impedance measurements. The fluid changes recorded using this method were compared to fluid volume changes measured in plasma water (PV) using 125I-albumin, and extra-cellular volume (ECV) using 51 Cr-EDTA before and after treatment, and total body water (TBW) changes reflected by continuous bed scale monitoring. Changes in impedance

correlated to TBW changes, r=0.80, pz 0.001, while correlations in changes in ECV and PV were: r=0.57 and r=0.55 respectively, p<0.05. Alterations in body fluid volumes recorded with whole body impedance is best correlated to total body water changes. The use of continuous whole body impedance monitoring has been shown to offer a simple non-invasive method for recording total body water changes during hemodialysis. . . . *Department of Surgery, Karolinska Institute and Hospital, 104 01 Stockholm SWE-INT. J. Clin. Montt Comut. 1990 7/3 (163-169)*

BIOELECTRICAL IMPEDANCE USED IN ASSOCIATION WITH ANTHROPOMETRY: EXPERIENCE IN A FIELD SURVEY OF UNDERPRIVILEGED GUATEMALAN CHIILDREN

Manolo MAZARIEGOS[(1)] Juan Carlos ROMERO-ABAL, Carlos Valdez, Carlos F. GRAZIOSO, and Noel W. SOLOMONS

ABSTRACT Bioelectric impedance (BIA) has been proposed to be used to evaluate nutritional status in clinical settings; however, given its simplicity and portability, there is a potential for using this technique in filed settings that has not yet been explored. Accuracy and precision are differentially important with respect to: a) prediction for an individual; b) change within an individual; and c) description of a population. We have explored the latter two issues in a cross-sectional (n = 2,652) plus longitudinal (n = 542) study in preschool children in a peri-urban community in Guatemala City. Based on anthropometric indices, most of the children could be classified as having linear growth retardation, but with appropriate weight-for-height. BIA index (BI = Height^2/R) showed a pattern of linear increase with age. Weight was the single most important variable that explained 80% of the variance in BI. When a subset of 542 children were re-evaluated at a one year follow-up, the expected increases in BI were seen. Their magnitude varied as a function of age and gender, ranging from 0.2 to 2.4 cm^2/Ohm per year, with an average of 1 cm^2/Ohm per year. . . . *Age and nutrition, volume 5, n° 2, 1994)*

CLINICAL MEASURE OF LEAN BODY MASS BY BIOELECTRICAL IMPEDANCE IN PERITONEAL DIALYSIS PATIENTS

Rebecca Schmidt, Cosme Cruz, Francis Dumler, Tom Lubkowski*, and Christina Kilates**

Malnutrition remains a major problem in End State Renal disease though malnourished peritoneal dialysis (PD) patients differ from their hemodialysis (HD) counterparts in whom protein malnutrition and weight loss predominate. High caloric loads in peritoneal dialtsate likely account for obesity in many PD patients whose state of protein malnutrition may be masked by weight gain and change in body habitus.

Bioelectrical impedance (BEI) accurately assesses body composition (BC) in HD patients and uncovers subtle changes in lean body mass (LBM) and escape indirect anthtopomorphic detection. Segregating parameters of BC is especially crucial to nutritional management of PD patients in whom weight gain may be fat mass (FM) rather than muscle acquisition.

Percent of FM by BEI (21 + 10) differed significantly (p=0.00001) from analagius values obtained by skin fold (SF) methods (30±10) in 55 PD patients irrespective to body weight. Like SF (p=0.002), BEI (p=0.007) correctly discriminated thin and overweight patients in terms both of FM percent FM. However, BEI results alone approached statistical significance when segregating thin and overweight patients by percent LBM (87+23 vs 77+10; p=0.007). Most strikingly, SF measures of LBM were equivalent universally and thus failed to separate then from overweight patients.

BEI is a sensitive clinical measure of BC providing specific quantitation of LBM/FM ratios in PD patients with unrecognized nutritional derangements. . .
Henry Ford Hosptial, Detroit MI 48202

ASAIO JOURNAL 1993 THE ADJUSTMENT OF POST-DIALYTIC DRY WEIGHT BASED ON NON-INVASIVE MEASUREMENT OF EXTRACELLULAR FLUID VOLUME AND BLOOD VOLUME

Jean-Paul P.M. de Vries, Harm-Jan Bogaard, Peter M. Kouw, Liem P. Oe, Paul Stevens, and Peter M.J.M. de Vries

ABSTRACT One of the major problems in clinical practice of hemodialysis is an incorrect estimation of post-dialytic (PD) dry weight. Underestimation of dry weight leads to hypovolemia-induced hypotension. Overestimation to hypertension pulmonary edema and left ventricular hypertrophy. Due to insensitivity of clinical variables in order to estimate dry weight a more accurate technique is warranted.

For this purpose and for the continuous surveance of changes in blood volume (BV) during hemodialysis two non-invasive techniques were applied. Based on post-dialytically obtained extra-cellular fluid volume (EFV) values, measured by means of a conductivity method, 30 stable hemodialysis patients were divided into three groups for further analysis: de- (n=9), normo- (n=15), and over-hydrated (n=6). Using an on-line optical reflection method, changes in BV were measured continuously during therapy. Mean BV decrease, corrected for UF, differed slightly between three groups (0=1.84± 2.06, N=3.20±1.80, D=4.20±1.60 % /L). However, eight hypotensive episodes occurred in group D versus none in group N and O. These hypotensive episodes were characterized by a greater reduction of BV corrected for ultra-filtration from the start of treatment until the moment of hypotention (6.96±2.21 % /L) compared to the 22 non-hypotensive controls (2.16±2.01 % /L, P<0.001). Based on the PD EFV dry weight of the over-hydrated patients

were decreased respectively increased by 500 g each following session, until PD EFV was within normal bounds. After adjustment of dry weight and BV fall tended to be lower in the D group, whereas the hypotension frequency decreased significantly (54±22 vs 14±13 %, P<0.025).

These data suggest that non-invasive measurement of PD EFV and continuous monitoring of changes in BV can assist in an accurate estimation of dry weight and a reduction of hypovolemia-induced-hypotension. . . . . *Department of Internal Medicine and Medical Physics, Free University Hospital, and Diatel. Amsterdam, The Netherlands*

USE OF BIOELECTRICAL IMPEDANCE (BEI) FOR THE NUTRITIONAL FOLLOW UP OF CHRONIC HEMODIALYSIS PATIENTS

Francis Dumler, Rebecca Schmidt, Tom Lubkowski*, Stan Frinak*, and Christina Kilates**

Although malnutrition poses a significant risk factor to the well being of chronic hemodialysis patients, (CHD), their nutritional assessment is usually empirical. Our previous work with BEI assessment of body composition in 103 CHD showed body fat content (FM) by BEI matched values obtained by the skin fold method (29+11 vs 29+9% respectively). Total body water content (TBW) by BEI closely correlated with results of anthropometric (R=0.957; P=0.0001) and urea kinetic modeling (R=0.096; P=0.0001. Techniques.

We have now prospectively studied body composition by BEI in 52 patients (mean age 59 + 14 years) followed for 8.3 + 3.6 months. When defined by deviation from ideal body weight (IBW), BEI correctly discriminated between weight (<2.5% of IBW) and overweight (2>2.5% of IBW) patients in terms of FM (22 +11% vs 33+ 9%; P=0.0009). LBM (80 + 8% vs 67 + 10%; P=0.0019 and TBW (59 + 5% vs 49 + 7%; P=0.001) respectively. Serial body weights longitudinally did not correlate with changes in LBM as measured by BEI. While 19% of patients lost body weight, 35% lost LBM; only 28% with decreasing LBM lost weight as measured post dialysis. An increase in LBM was observed in 25% of patients; of these only 46% gained post dialysis body weight. Most striking is the contrast between the patients who showed no change in LBM and BEI and those whose body weight remained neutral (13% vs 58%).

BEI is a most sensitive clinical tool for assessing changes in LBM in hemodialysis patients. . . . .*Henry Ford Hospital, Detroit, MI 48202*

"NUTRITIONAL ASSESSMENT USING BIOELECTRICAL IMPEDANCE ANALYSIS (BIA) IN CHRONIC HEMODIALYSIS (HD) PATIENTS"

GM Chertow, EG Lowerie, DW Wilmore, J. Gonzalez, MN Gottlieb, MS LeBoff, NL Lew, W Huang, B Zebrowski, JM Lazarus, Brigham & Women's Hosptial, National Medical Care, Harvard Medical School, Boston, MA

Protein energy malnutrition (PEM) effects a large proportion of HD patients. Body Cell Mass (BCM), a valid measure of nutritional status, can be estimated by whole body potassium, or a combination of Dual-Energy-X-Ray-Absorpiometery(DEXA) and Deuterium Oxide(D2O) and Sodium Bromide(NaBr) dilution(D). BIA is an accurate, non-invasive method of measuring Total Body Water (TBW) using Resistance(R) and Reactance(Xc) to a high frequency, low-amplitude electrical current, but has not been validated in the nutritional assessment of HD patients. We evaluated 28 chronic HD patients with simultaneous DEXA, D2O, NaBr and BIA (age 57 +/- 11years, 50% female, 50% non-white, 25% diabetic, body weight 73.5 +/- 18.1 kg range, 44-116 kg. Mean +/- SD)

	DEXA-D	**BIA**	**Spearman r**	**P**
TBW	41.6 +/- 10.8	38.4 +/- 9.9	0.98	<0.0001
BCM	32.9 +/- 9.8	26.9 +/- 6.6	0.92	<0.0001

As expected, TBW by BIA was strongly correlated with TBW by D2O. DEXA – dilutional BCM was calculated: DEXA total weight – DEXA bone mass – DEXA fat mass – NaBr(ECW). BCM by BIA was calculated by proprietary software ("Fluid & Nutrition Analysis: version 3.0, RJL Systems, Clinton Twp. MI) BIA BCM was also strongly correlated with DEXA-D BCM, but modestly underestimated. The ECW/TBW ratio by NaBr: D2O dilution was 0.34 +/- 0.04; this was strongly correlated with the Xc/R ratio($r=0.77, P<0.0001$).

Conclusions: HD patients are prone to accumulation of ECW and to loss of visceral and somatic protein stores, which contribute to morbidity and mortality. Measurements of changes in body weight or Lean Body Mass (LBM) may be insensitive to the development of PEM or ECW overload in HD patients. Nutritional assessment in HD patients should focus on BCM rather than LBM. The Xc/R ratio may aid in the recognition of ECW excess in HD patients.

DETERMINATION OF EXTRACELLULAR FLUID VOLUME USING IMPEDANCE MEASUREMENTS

Espejo MG;, Neu J; Hamilton, L; Eitzman B; and others

ABSTRACT Currently, accurate determination of body fluid compartments depends on the sodium bromide method (NaBr), an invasive

measurement requiring venipuncture with infusion of a foreign substance. Impedance (Z) measurements may provide a practical noninvasive alternative for estimating fluid compartments in sick, premature, neonates. To validate the impedance method, we compared it with the NaBr technique in nine anesthetized rabbits. Electrodes were placed for impedance measurement. Vascular catheters were inserted into the femoral artery and vein. Baseline impedance data were collected at 1.0 kHz and blood samples were drawn for NaBr standard assay. Using conventional assay techniques for determination of extra-cellular fluid volume (ECFV), we correlated NaBr data with impedance measurements. A linear relationship between ECFV by NaBr assay and the previously developed impedance equation rho L2/Z1.0 was established using regression analysis. A correlation value of r= .95 was obtained. These date suggest that potential for impedance to estimate ECFV. . *Department of Pediatrics, University of Florida College of Medicine Gainesville, Critical Care Med. 1989 Apr. 17 (4):360-3 Unique Identifier, Medline 89196021.*

Bioelectrical Impedance Analysis: A Review of Principles and Applications

Kushner, RF

ABSTRACT Whole-body bioelectrical impedance analysis (BIA) is widely used by researchers and clinicians as a noninvasive and safe method to estimate body composition and body water volume in children and adults. Development of new approaches, such as segmental and multi-frequency analyzers, should greatly expand the utility of this electrical technique. This article reviews the principles, underlying assumptions, clinical applications and future directions of the BIA method. . . . *Clinical Nutrition Research Unit, University of Chicago. Review Article: 71 Refs., J. Am Coll, Nutr, 1992 Apr;11(2):199-209, Unique Identifier: 92251069*

BODY COMPOSITION AND LIPID ABNORMALITIES IN HISPANIC AND BLACK PATIENTS ON CONTINUOUS AMBULATORY PERITONEAL DIALYSIS

Mario A. Henriquez, Alfredo Gonzalez, James A. Bemis,[1] and Jorge Esquivel

Cardiovascular disease is the leading cause of death in patients undergoing maintenance dialysis. This study was undertaken to evaluate the lipid abnormalities and body composition by bioelectrical impedance in patients receiving continuous ambulatory peritoneal dialysis (CAPD). The patients were between the ages of 28 and 77 and had been on dialysis for periods ranging from 6 – 48 months. Body composition studies performed by electrical impedance showed that the CAPD patients generally had elevated levels of body fat ratios of more than 1.0, and lean tissue was decreased. Serum chemistries showed that most of the patients had waist-to-hip fat ratios of more than 1.0, and lean tissue was decreased. Serum chemistries showed that most of the patients had albumin levels less than 3.5 g/dL. The most

frequent lipid abnormalities found were: hypertriglyceridemia; hypercholesterolemia; decreased HDL levels, elevated cholesterol/HDL and apoproteins (Apo B/A-1); and elevated lipoprotein [Lp(a)] levels. Cardiovascular disease was prevalent in the patients studied. Ten had a positive history of angina, with three documented myocardial infarction and two documented cardiovascular disease. In conclusion, standard CAPD treatment may increase the risk of cardiovascular disease. . . . *Per. Dialysis International, Volume 13, Supplement 2, Copyright Ó 1993 International Society for Per. Dialysis, 0896-8608/93*

BIOELECTRICAL IMPEDANCE ANALYSIS (NOT BODY WEIGHT): A GUIDE TO POSTOPERATIVE FLUID MANAGEMENT IN COMPLEX CATABOLIC PATIENTS

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Postoperative fluid and nutritional management are commonly guided by changes in body weight (ΔWT); however, ΔWT inaccurately represent changes in total body water. (ΔTBW) when accompanied by rapid changes in body fat (BF) and protein (BP). Bioelectrical impedance analysis (BIA), a technique which determines TBW, defines the proportion of ΔWT which is due to water, allowing the combined change in BF and BP to be determined by subtraction. To investigate the relationship between ΔWT and ΔTBW, 7 lung transplant recipients were followed until discharge. Daily BIA measurements were used to determine ΔTBW which was compared to ΔWT. In two of the patients, cumulative caloric and nitrogen balance were used to determine the change in BF and BP; subtracting these from ΔWT gave an alternative measure of ΔTBW, which was compared to that obtained by BIA. Data represent rates of change over 7 days for the patients, who were generally stable, during the first two weeks following operation (mean±SEM).

Number of Pts.	Δ**Wt (kg/wk)**	Δ**TBW (L/wk)**	**Combine Change In BF + PB (kg/wk)**	**Change in BF +BP From balance (kg/wk)**
7	-1.54±0.75	+0.96±0.97*	-2.44±0.393	_____
2	-1.40±2.45	+0.40±2.56	-1.80±0.11	-1.64±0.34

*p= 0.018 vs ΔWt by Wilcoxon signed-rank test

Determination of the combined change in BF and BP by balance verified the determination of TBW by BIA and explain all but 0.16 kg of ΔWT. Over the one week period a mean loss of 1.5 kg was observed, as opposed to a mean TBW gain of nearly 1 liter. Over a three week period, the tendency for fluid retention became even more pronounced with a maximum water gain of 5.1±0.57 liters and a corresponding weight gain of 2.5±0.69 kg. The data

suggest that ΔWT inaccurately reflects changes in hydration in complex catabolic patients and masks the loss of body tissue.. Serial BIA offers a more sensitive index of measuring the fluctuations in TBW and , when used in combination with ΔWT, can more accurately define the severity of a catabolic response and assess the appropriateness and nutritional intervention.

BODY COMPOSITION ANALYSIS BY WHOLE-BODY IMPEDANCE PLETHYSMOGRAPHY FOR THE ASSESSMENT OF FLUID & NUTRITION IN HEMODIALYSIS (END-STAGE-RENAL-DISEASE)

Recommendations from the National Institutes of Health Consensus Development Conference on Morbidity and Mortality of Dialysis (NIH Consensus Statement, Volume 11, Number 2, November 1-3, 1993) include;

1) quantitative methods are needed to objectively evaluate the relationship between the delivered dose of dialysis and morbidity and mortality.
2) factors contributing to the under/over-dialysis include dialysis does adherence and under-prescription.
3) early detection and treatment of malnutrition contribute to improved survival of patients on dialysis.
4) linking direct reimbursement for nutritional care to outcomes should be explored.
5) newer techniques such as bio-impedance analysis offer promise for ease, reproducibility and accuracy for assessing states of fluid overload and nutrition status.

Bioelectrical impedance analysis is a simple, inexpensive and non-invasive technique to assess body composition. The measurement is completed with two pair of surface electrodes placed in relation to anatomical landmarks at the wrist and ankle. A harmless low-voltage, high-frequency electrical signal is used to establish an electrical field with the patient becoming the circuit. The study is completed in less than five minutes and limited compliance requirements. Measured values of impedance (resistance/reactance) are read directly from the impedance analyzer and the values are entered into a software program for results. Each electrical value relates to a specific compartment of fluid volume; resistance inversely to water and reactance proportionate to cell volume. The results include: Total Body Water or volume status, Fluid volume distribution Intra-Cellular Water & Extra-Cellular Water, Body Cell Mass, Body Fat and Basal Metabolic Rate.

These values enable the nephrologist to establish quantitative values for monitoring fluid accumulation between treatments. The specific volume within the proper compartment can be established and tracked before, during and after dialysis to ensure an effective dose. Volume can be reduced to known quantitative values reducing the occurrence of under/over dialysis and hypotensive episodes. The dialysis dose can be adjusted accordingly so as to

optimize the therapy by not leaving available fluid or by removing so much fluid as to induce hypotensive complaints or catabolism. Nutrition status can be assessed with greater sensitivity and specificity than current modeling and chemistry analysis techniques. Earlier intervention reduces treatment times

and increases potential treatment effectiveness. The quantitative analysis of protein tissue compartments can be used to initiate nutrition support and monitor effectiveness.

Outcomes can be documented as to the adjustment of post-dialytic dry-weights, prevention of hypotensive complications, nutrition assessment and treatment. Standardization of therapies, comparison of response rates, treatment intervention effectiveness, co-morbid episode management are also affected by impedance assessment. Morbidity and mortality impact can be documented.

Present reimbursement is through standard CPT codes, 93720, 93721, 93722 from Medicare, Medicaid and private carriers. The reimbursed amount varies from state to state from $40.00 to $120.00. The value is set to "normalize" in 1996 to $60.00 per evaluation. Case managers generally allow studies to be paid for every two-weeks during acute care phases, TPN treatment and less frequently when the patient is stable. The disposable cost incurred per study is approximately less than $1.00.

Use of multi-frequency bioelectrical impedance analysis for the estimation of extra-cellular fluid

Van Loan MD; Mayclin PL

ABSTRACT Thomasset (Lyon Medicine (1962): 207, 107-118; (1963) : 209, 1325-1350; (1965): 214, 131-143) and others suggested that low-frequency impedance measurements could be used to estimate extra-cellular fluid and that high-frequency measurements could be used for the assessment of total body water. It was the purpose of this study to examine the relationship between body fluid compartments and multi-frequency bioelectrical impedance analysis (MF-BIA). Total body water (TBW) and extra-cellular fluid (ECF) were measured using deuterium and sodium bromide dilution procedures. Intracellular fluid volume (ICF) was calculated as the difference between TBW and ECF. A tetrapolar arrangement of surface electrodes was used to measure whole-body resistance (R), reactance (Xc), impedance (Z), and phase angle (P) at 25 frequencies ranging from 1 kHz to 1.35 MHz. Subjects (n = 60; 40 male and 20 female) were between the ages of 19 and 65 years. Mean ratios (+/- SEM) of ECF / ICF and ECF / TBW were 0.83 +/- 0.021 and 0.45 +/- 0.011, respectively. Individuals with the largest fat-free mass (FFM) had the highest ECF value. Whole-body resistive index values most correlated to ECF were at 224, 300, 400, 548 and 1 kHz

with correlations ranging from 0.93 to 0.84. All possible subset regression analysis was used to develop a prediction equation for ECF: R2 = 0.9322*WT) – (1.3962*SEX), where RI = resistive index (HT2/R) at the specific frequency of 224kHz; WT = weight in kilograms; sex was dummy-coded, males = 0, females = 1. . . . . *Eur J Clin Nutr, 1992, Feb;46(2) : 117-24, Unique Identifier: 92217563*

Bio-Electrical Impedance Analysis (BIA): A method of measuring the condition of nourishment in patients with HIV infections in various states

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ABSTRACT Purpose of the Tests: Bio-electrical impedance analysis is a method of determining total body water (TBW), fat free mass (LBM), body fat, body cell mass (BCM) and extra cellular mass (ECM). To determine whether a loss of body cell mass is apparent in the early stages of HIV infection, we used BIA to test 195 patients in various stages of HIV infection (Frankfurt classification) and compared the data with the test results of 340 normal population.

Methodology: BIA, thru resistance measurements, indicates total body water. From that lean body mass (LBM) can be calculated. The phase angle of BIA indicates the difference of LBM/ BCM and ECM. Compared was the body weight (kg), body mass index (BMI), body cell mass (BCM) and ECM/BCM ratio of (n – 340) healthy males with HIV infected patients (n = 195) in various states.

Results: HIV infected patients in comparison to the normal population indicated already in state 2a of their disease a significantly lower body cell mass with a comparable body weight and BMI. The reduction of BCM with a sustained or increasing ECM is indicated in the BIA measurements by a significantly lower phase angle and an increase of ECM/BCM ratio.

	AGE	**KG**	**BMI**	**Phase/Angel**	**BCM**	**ECM/BCM**
Control Means	36.4	79.2	25.1	6.79	35.8	0.828
n = 350 ± Std	16.9	12.8	3.35	1.16	7.25	0.164
Stage 2a means	36.9	79.8	24.8	5.76	31.9	0.987
n = 26 ± Std	11.8	12.0	3.35	0.71	4.34	0.144
P <	na	na	na	0.001	0.007	0.001
Stage 2b means	38.8	72.2	23.0	5.41	28.7	1.084
n = 87 ± Std	10.6	9.96	2.92	0.87	4.91	0.251
P <	na	0.001	0.001	0.001	0.001	0.001
Stage 3 means	39.6	66.6	20.9	4.56	24.2	1.351
n = 82 ± Std	8.41	11.1	3.14	.090	5.44	0.355

P <	na	0.001	0.001	0.001	0.001	0.001

Conclusion: HIV infected patients in state 2a of their disease already show a change of "body composition" as it would appear in malnourishment. This is not indicated in weight loss or pathological BMI, but thru a lower BCM and an increased ECM/BCM index compared to the normal population. These patients should be treated with dietary supplements in the early stages of their disease. . . . . *German AIDS Congress, November 235 – 27, 1990, Hamburg, Germany*

Body-fat measurement in patients with acquired immunodeficiency syndrome: which method should be used?

Wang, J; Kotler DP; Russell M; Burastero S; and others

ABSTRACT: Malnutrition is common in patients with acquired immunodeficiency syndrome (AIDS), which distorts the chemical contents in the fat-free mass (FFM) and alters the assumptions underlying the traditional methods for calculating body-fat content so that such measurements may be not be accurate. In vivo neutron-activation analysis (IVNA) measures FFM independently of the traditional assumptions, thereby providing more accurate measurements of body fat. We compared seven methods for measuring body fat in 18 male patients with AIDS: INVA, total body water (TBW by 3H2O dilution), total body potassium (TBK by 40K counting), dual-photon absorptiometry (DPA), bioelectrical impedance analysis (BIA), and two well-calibrated anthropometric methods. FatTBW and fatDPA were not significantly different from fatIVNA. Fat TBW gave the highest correlation with fat IVNA and the smallest SEE of +/- 1.8% (1.1 kg). The traditional and widely available TBW and the newer DPA method provide reliable estimates of fat IVNA in patients with AIDS. . . . *Am J Clin Nutr 1992, Dec;56(6) : 963-7, Unique Identifier: 93071812*

Clinical risk factors for malnutrition in HIV-1 infected patients.

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ABSTRACT: OBJECTIVE: To estimate the influence of fever, diarrhea, state of HIV disease, opportunistic infection and anorexia on malnutrition in HIV-infected patients we analyzed data of patients undergoing a nutritional counseling program from November 1989 to April 1992. PATIENTS AND METHODS: Our study group comprised 104 HIV-infected patients (98 homosexual men, 15 a-symptomatics, 30 AIDS-related complex patients, 59 AIDS patients). Nutritional status was measured by previous weight loss, bioelectrical impedance analysis and prospective intake protocol.

RESULTS: Patients had lost 10 +/- 8.7% of body weight. Compared with controls, body mass index was lower ($P < 0.001$), and extra-cellular/body mass ratio (ECM/BCM) was higher ($P < 0.001$). BMC was reduced proportionately to weight loss, percentage of body fat was lower compared with controls ($P < 0.001$), even in patients with stable weight. Clinical risk factors for malnutrition were identified as fever in 31, diarrhea in 26, acute infections in 42 and anorexia in 73 out of 104 patients. One single risk factor was predominant in 63 patients: fever in five diarrhea in 14, acute infections in 17 and anorexia in 27 patients. Weight loss was not linearly correlated to CD4 count or to time since AIDS diagnosis. Flood intake was highly variable (39-165% of calculated needs) without correlation to weight loss. CONCLUSIONS:Loss of body fat was found even in the earlier stages of HIV infection and was more severe than loss of BCM. Important risk factors for malnutrition are anorexia (most frequent), diarrhea and fever (most severe). Most patients have combined risk factors. Treatment strategies and pathophysiologic studies should consider the heterogeneity of HIV-associated malnutrition. . . . . *Dept. of Internal Medicine I, University of Cologne, Germany, AIDS 1993, Sep;7(9) : 1213-9, Unique Identifier: 94030752*

Alterations in body fluid content can be detected by bioelectrical impedance analysis.

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ABSTRACTS: The electrical resistance across the whole body and its segments to the conduction of a weak alternating current was determined in human subjects under three different conditions: (1) during bed rest, (2) during infusion of 1 liter of saline, and (3) during donation of 1 unit of blood. During bed rest, extra-cellular and total body water were measured by dilution of bromide and heavy water, respectively. Electrical resistance obtained from electrodes placed on proximal portions of extremities (proximal resistance) accounted for less than 50% of that determined by electrodes positioned on routinely used portions of a hand and foot (whole body resistance). Following saline infusion, resistance determined from the whole body and all it segments fell (P less than 0.001); the magnitude of the drop in both proximal and whole body resistance was inversely related to the volume of total body water (TBW) ($r = -0.82$, P less than 0.002, and $r = -0.73$, P less than 0.01, respectively). In contrast, blood donation was associated with significantly increased resistance at both measurement sites. TBW predicted from anthropometrics was inversely related to both proximal ($r = -0.75$, P less than 0.001). Bioelectrical impedance analysis is a simple technique which may be useful in monitoring minimal alterations in TBW. Furthermore, altered fluid status may be predicted more accurately by changes in proximal resistance compared to changes in traditionally used whole body resistance. . . . *Dept. of Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA 02115, J Surg Res 1991 May;50(5) : 461-8, Unique Identifier: 91245791*

Relation of Total Body Reactance to Resistance as a Predictor of Mortality in Septic Patients

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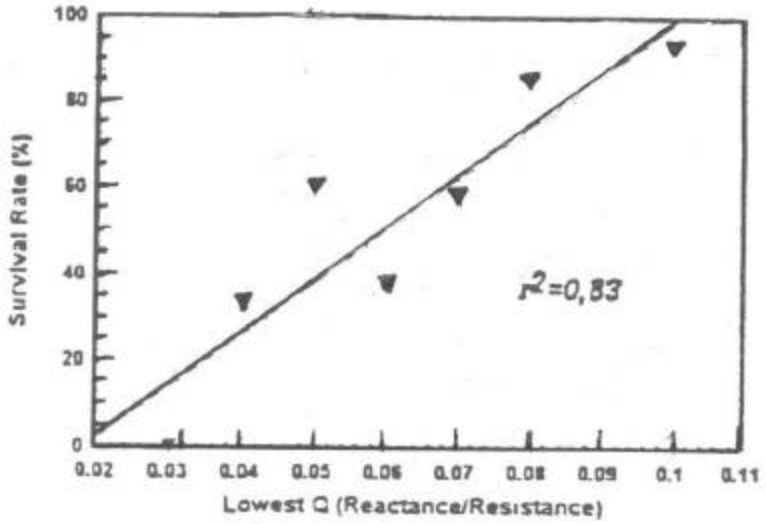
Total body reactance (Xc) measured by bioelectrical impedance analysis correlates with intracellular water, while total body resistance (R) correlates with total body water. The aim of our study was to examine if the relation Xc/R (Q) is indicative of the disturbed cellular membrane function in sepsis and can be related to the outcome of septic patients.

Methods: R and Xc were measured sequentially on 1441 treatment days in 232 intensive care patients. According to clinical data, patients were classified as septic (S, n=40) or non-septic (NS, n=181). Eleven patients could not be allocated unequivocally. Results were compared to 301 normal volunteers (N).

Results: At the time of admission, mean (±SD) Q was 0.081±0.022 in S compared to 0.105±0.022 in NS ($p<0.001$). Both groups were significantly lower compared to N (0.119±0.016). During treatment Q decreased more in S than in NS (0.068±0.020 vs. 0.95±0.024). While in surviving patients the lowest measured Q was 0.096, it was 0.071 in patients with fatal outcome. There was a linear relation between the lowest measured Q and mortality.



Conclusion: The decrease in the relation Xc/R, which can be readily measured in intensive care patients, indicates the shift from intracellular to extra-cellular water and thus marks the disturbed cellular membrane function of septic patients. The quotient correlates highly with mortality and could be used for the staging of study patients.

A Cross-Sectional Study of Body Composition in Hemodialysis Patients

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Protein energy malnutrition (PEM) has been reported in 20-40% of HD patients and clearly contributes to morbidity and mortality. We have previously shown that bioelectrical impedance analysis (BIA) is a reproducible and valid method of body composition analysis in hemodialysis (HD) patients. BIA (800 mA, 50 KHz) was performed pre-dialysis on 2020 HD patients. Height, body weight, resistance (R) and reactance (Xc) were measured; body mass index (BMI) and Xc/R ratio were calculated. Total body water (TBW) and body cell mass (BCM) were estimated using proprietary software (RJL Systems) and adjusted to body weight (TBW%, BCM&).

Parameter	**Male (n=1051)**	**Female (n=969)**
Body Weight (kg)	78.3 ± 17.7	69.1 ± 18.1
BMI (kg/m2)	26.2 ± 5.6	27.3 ± 7.5
Resistance (Ω)	470.4 ± 85.5	539.6 ± 100.6
Reactance (Ω)	41.4 ± 14.2	40.5 ± 15.0
Xc/R	0.089 ± 0.03	0.077 ± 0.03
TBW (kg)	45.8 ± 8.2	34.2 ± 5.6
TBW% (%)	59.4% ± 7.1%	51.1% ± 8.6%
BCM (kg)	29.6 ± 5.1	21.6 ± 3.0
BCM% (%)	38.7% ± 6.9%	32.8% ± 7.4%

Despite generalized extra-cellular fluid overload along with interdialytic water weight gain, TBW% was paradoxically reduced compared with normals, especially among women. BCM% was similarly reduced. The pattern of diminished BCM and TBW was supra-normal BMI is most consistent with loss of muscle mass and kwashiorkor (protein depletion with adequate energy intake and stores).

Conclusion: Prior studies may have underestimated the prevalence of PEM in HD patients, which may exceed 50%. Valid estimates of TBW and BCM using BIA may be useful in nutritional assessment and urea kinetic modeling. Studies are ongoing to determine the incremental predictive value of R, Xc, Xc/R, and estimated body compartments on morbidity and mortality in HD patients. . . . *Renal Division, Brigham and Women's Hospital, Harvard Medical School, Boston MA, National Medical Care, Inc., Waltham, MA*

Bioelectrical impedance and body composition

Assessment of changes in body composition can take the form of long-term changes in fat and fat-free mass in response to disease severity and treatment, or short-term changes in individual patients and body compartments such as total body water. Data on the use of a straightforward non-invasive technique

for short-term assessment-bioelectrical impedance-have lately been reported.[1,2]

The basis for this method is that the only medium that can conduct electricity within the body is water. Thus, the anhydrous nature of fat, restricts the flow of electrical current to the lean body mass. Extra-cellular water offers a simple resistance to the flow of current. Equally, there is a resistance offered to the current due to intracellular water. Cell membranes likewise have a resistance and also act as small imperfect capacitors, offering a resistance in the form of reactive capacitance. At high frequencies the reactive capacitance of the cell membrane becomes very small since it is related to the reciprocal of current frequency; this effectively short-circuits the membrane resistance. Consequently, there is a flow of alternating current through both the extra-cellular and intracellular water compartments. Electrical theory indicates that the volume of body water will be related to the length of the conductor squared divided by impedance, so measurements of impedance are usually expressed as the square of height (or supine length)/impedance.

The technique is simple and inexpensive, and gives immediate results. Two Reports[4,5] suggest that the method is especially useful for monitoring total body water after cardiac surgery. The first one of these studies took the opportunity to validate specifically the bioelectrical impedance technique against measures of total body water by use of a stable isotope. The researchers were encouraged by a good correlation ($r = 0.91$) between measured total body water with a deuterium oxide dilution technique and the square of height/impedance. Their data suggest that impedance is a satisfactory and reliable method of estimating total body water in children who require critical cardiac care. Similar conclusions were drawn by the second group of researchers,[5] who assessed the ability of bioelectrical impedance to monitor changes in hydration status after cardiac surgery in adults. These findings suggest that the technique has potentially widespread applications. Several groups[3-5] have pointed out that the regression equations used to predict total body water from impedance are remarkably similar in very different populations, including patients with chronic renal failure, congestive heart failure, inflammatory bowel disease, diabetes, growth hormone deficiency, cancer, and obesity. The regression coefficient is close to 0-6 and the intercept close to zero. This ability to predict total body water in such a wide range of conditions coupled with the ease of measurement makes the technique especially attractive for clinical applications.

Bioelectrical impedance has been used[6,7] to predict lean body mass, the underlying assumption being a constant and known level of hydration in lean tissue. This assumption could produce an uncertain and large error in estimation of lean tissue and hence fat tissue. Levels of hydration vary within healthy individuals and more so in those who are ill.

The technique should be judged primarily on its ability to predict total body water. Some manufacturers claim that multi-frequency impedance methods might allow measurement of intracellular and extra-cellular water

compartments. If this proves to be true, bioelectrical impedance becomes more valuable still.