

Bioelectrical Impedance Analysis (BIA) and Phase Angle

Introduction

Impedance analysis is based upon relating the measured electrical values of a subject to their physiologic equivalents as determined when the subject is the only unknown part of a safe and controlled electrical circuit. The properties of the circuit are well-defined and don't change over time. The method is precise, sensitive and specific in its ability to illustrate the changes inherent in the biological subject. Of particular benefit is these changes occur at a level of physiology that precedes those seen through biochemical assays, cell counts, imaging techniques and physical signs. This 'snapshot' of cellular level dynamics and architecture provide valuable additional data to clinical practice and medical research. *Michael Singer* (mgsinger@ipgdx.com)

History

The first electrical impedance measurements of biological variables of the circulation began at New York Post Graduate Hospital in 1939 with Dr. Jan Nyboer, Dr. Robert Halsey, Dr. Avrom Barnett and an engineer Mr. Samuel Bagno.

In 1938 Mr. Bagno was awarded U.S Patent No. 2,111,135 titled "APPARATUS AND METHOD FOR DETERMINING IMPEDANCE ANGLES," that discloses an apparatus for measuring the electrical phase displacing properties or impedance angle of humans, animals, and vital tissues. There is also disclosed a method for measuring the phase angle due to the impedance of an animal having properties of varying resistance and capacitance due to changes in muscular tension, comprising the steps of passing an alternating current through the animal, and measuring the phase during changes of resistance and capacitance.

In 1967 Thomasset was awarded U.S Patent No. 3,316,896 titled "APPARATUS AND METHODS FOR THE MEASURE OF THE ELECTRICAL IMPEDANCE OF LIVING ORGANISMS," which discloses a method for simultaneously and associatively determining the individual impedances of the extracellular contents and the intracellular contents of a living organism, which consists in measuring the total impedance of the organism between two selected points at predetermined frequencies.

A search of the the US patent office and peer review papers on topics of bioelectrical impedance analysis (BIA) and phase angle (PA) will illustrate how many years this concept has existed. A more recent patent by Michael Singer (6,587,715 July 1 2003) discusses the broad use of resistance, reactance and phase angle as a method for determining illness, progression to death, and timing of death of biological entities.

What is Phase Angle ?

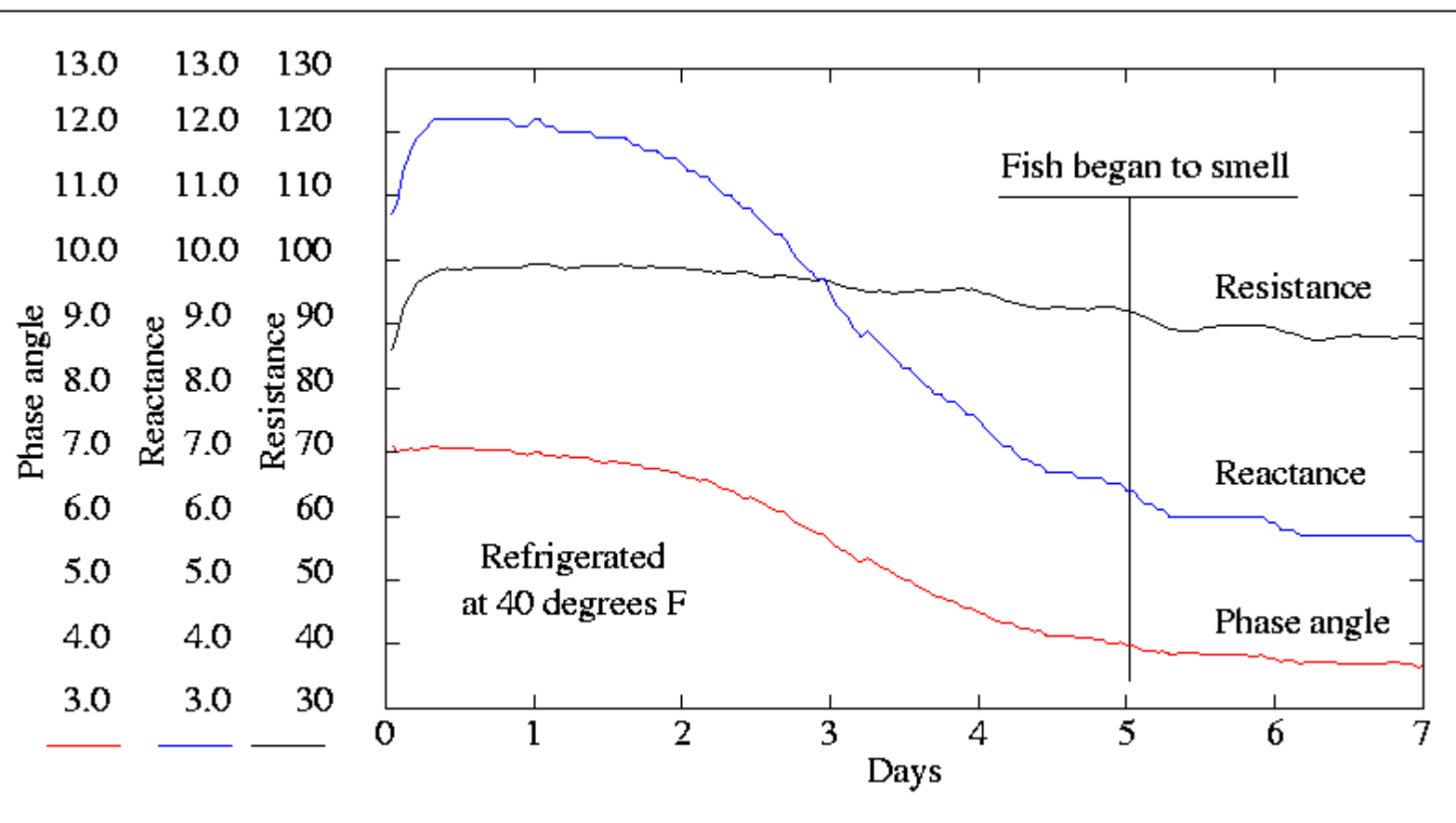
Phase angle is calculated by finding the ratio of reactance divided by resistance, and taking the arctangent of that ratio. Phase angle is normally expressed in degrees. The energy of all living things comes from cells that consume oxygen and nutrients and expel carbon dioxide and waste. The quantity and efficiency of cells directly affect phase angle. The outer boundary of the cell is a plasma membrane of phospholipid molecules that are a dielectric to form an electrical capacitor when a radio frequency signal is introduced to the cells environment. Capacitance is fundamental to any human phase angle measurement, the higher the capacitance the greater the phase angle. An elite athlete would have a higher phase angle than a sedentary person. It has been well documented that phase angle declines with disease, age and reduce activity level.

Further discussion of Phase Angle and Capacitance can be found in the paper [Principles of Bioelectrical Impedance Analysis](#).

Phase angle sensitivity

Fresh fish

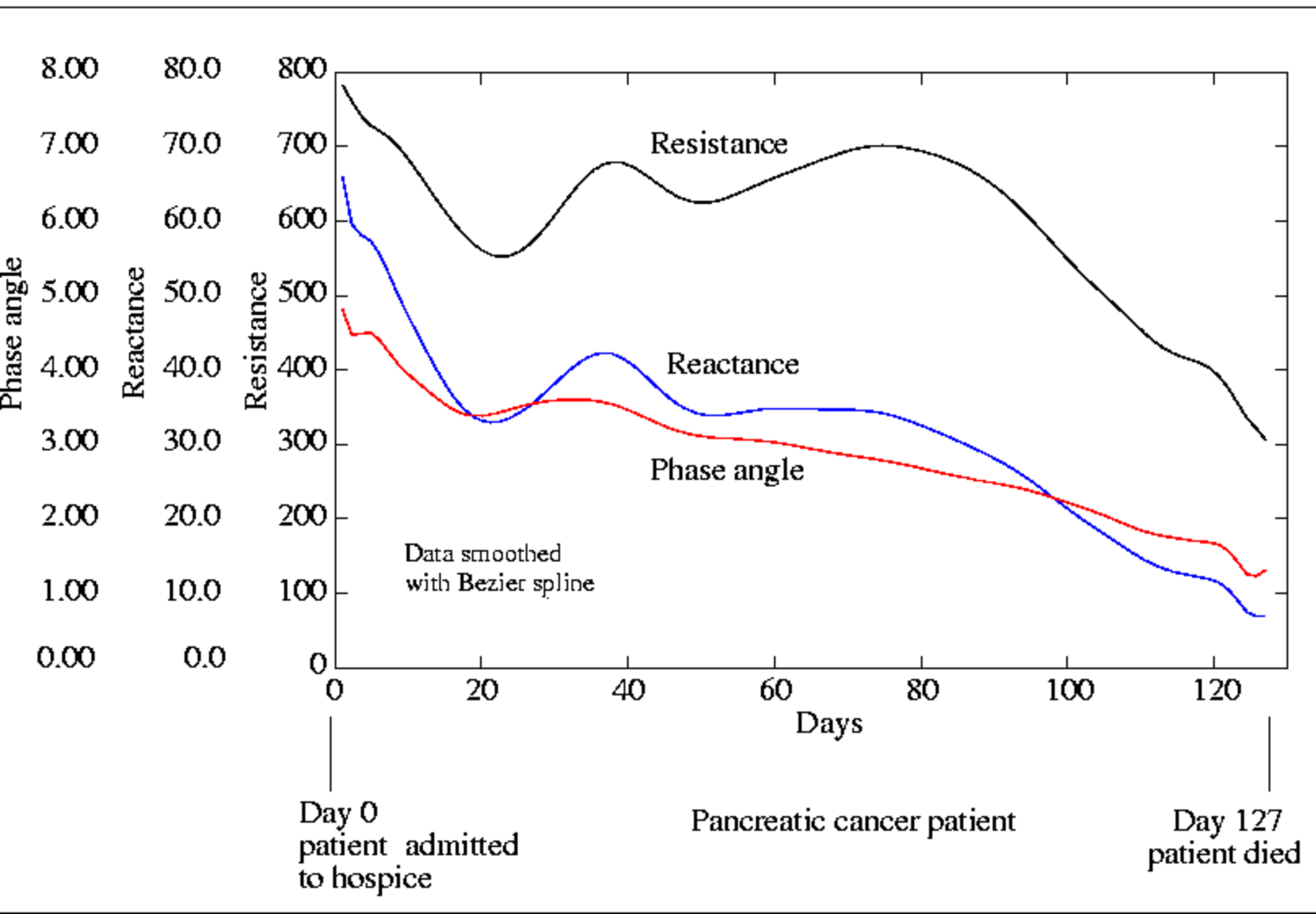
Phase angle sensitivity can easily be demonstrated by measuring resistance and reactance of a piece of fresh fish in real time. A Quantum II Desk top was configured to sample resistance and reactance each hour for a period of one week. The piece of fish is a net of Pickerel caught in Lake Erie and is not more than two days from when it was caught.



The initial upward slopes of resistance and reactance at day 0 are a result of the piece of fish stabilizing to 40 degrees Fahrenheit, phase angle does not change. After day one reactance begins to decline due to the break down of the plasma cell membranes and reduction in intracellular volume. Resistance is the ionic conductor or extracellular volume and remains relatively constant.

Pancreatic cancer patient

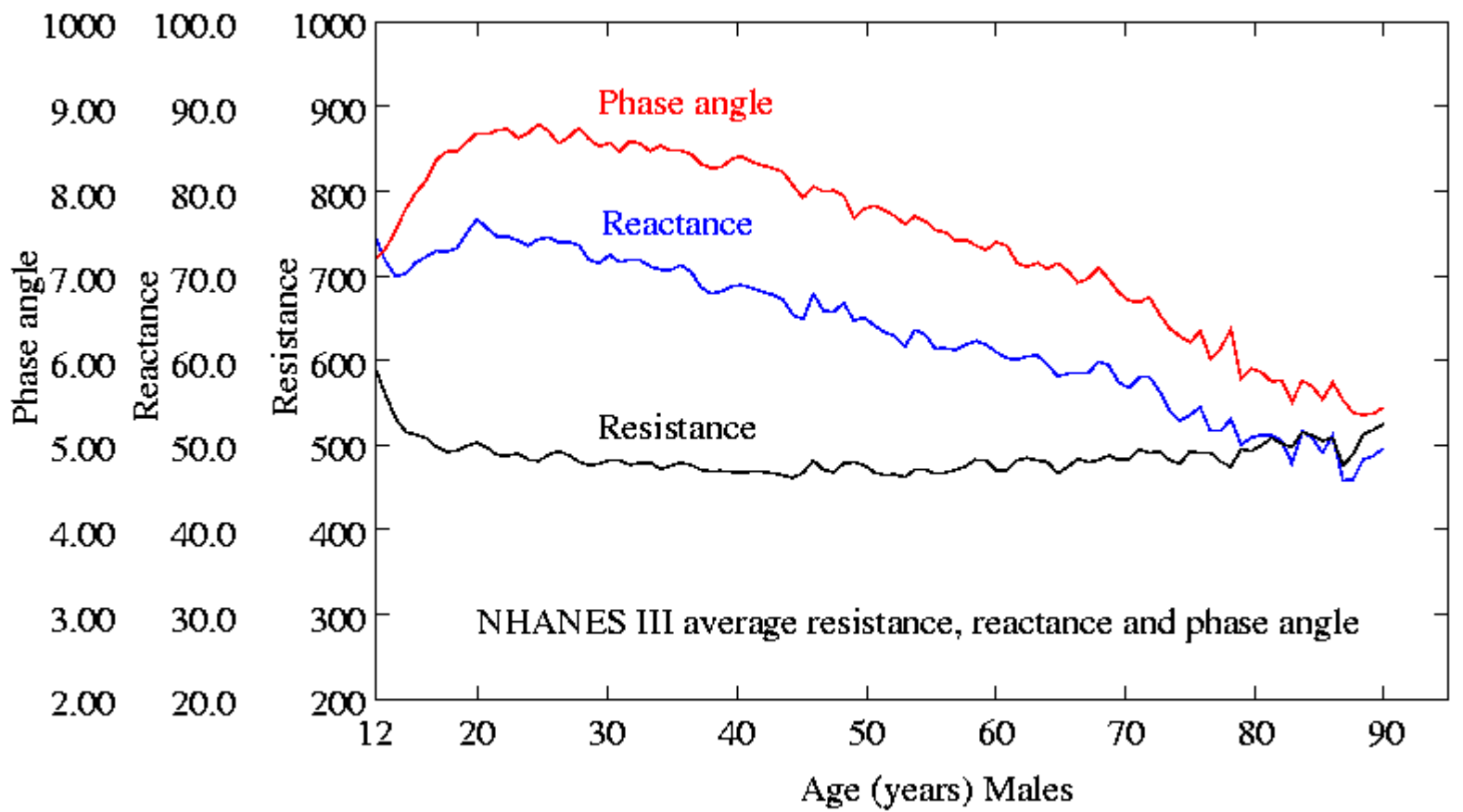
In late December of 1992 a male pancreatic cancer patient (age 71, height 69 inches) was admitted to the hospice program of the University of Indiana. A nurse assigned to this patient took BIA measurements each day for the last 127 days of the patient's life. The patient eventually died in early May of 1993.



NHANES III Males and Females

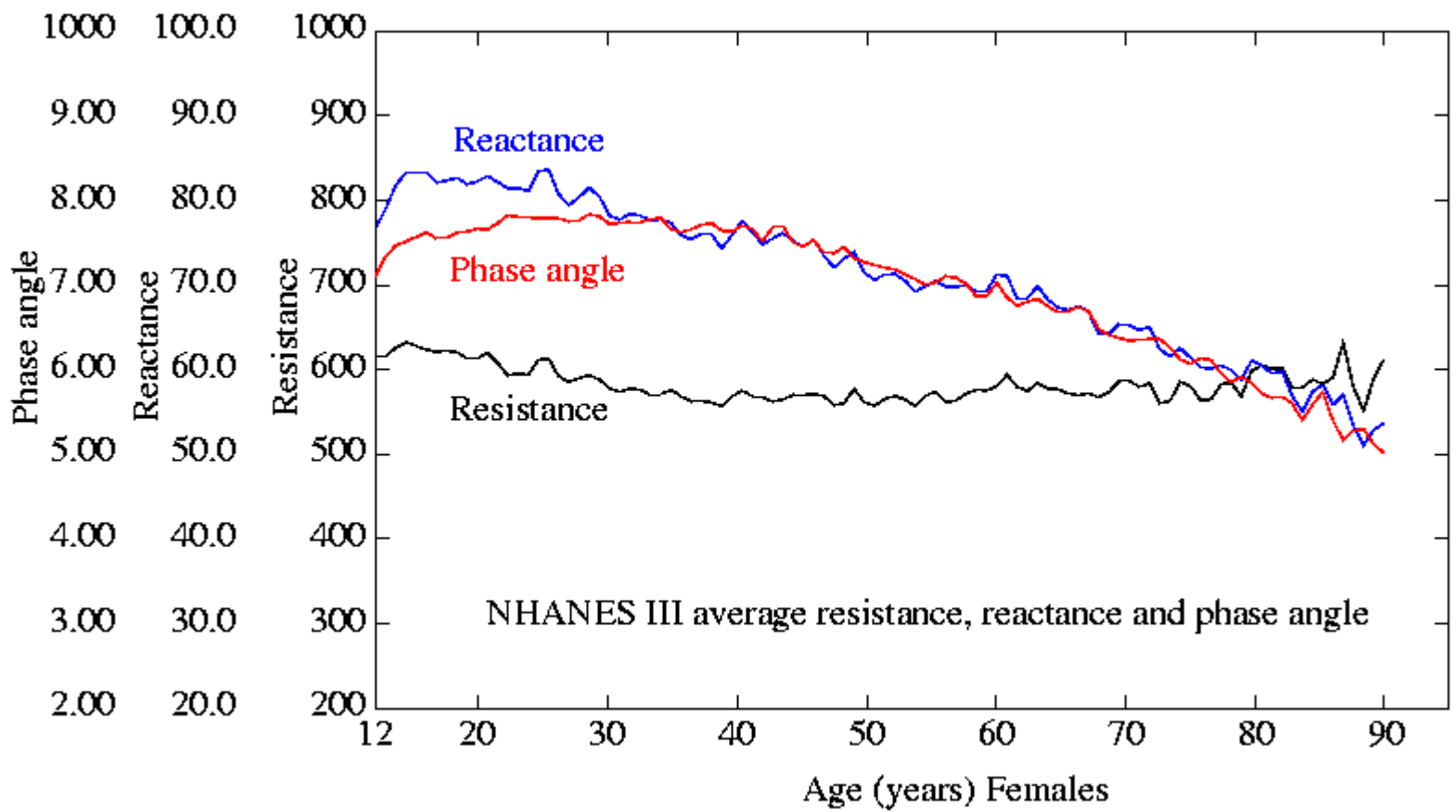
The Third National Health and Nutrition Examination Survey (NHANES III), 1988-94, was conducted on a nationwide probability sample of approximately 33,994 persons 2 months and over. The survey was designed to obtain nationally representative information on the health and nutritional status of the population of the United States through interviews and direct physical examinations. BIA data was collected on males and females who were 12 years and older.

NHANES III Males



NHANES III Males									
Age:	12 to 19 n=1379	20 to 29 n=1553	30 to 39 n=1383	40 to 49 n=1155	50 to 59 n=792	60 to 69 n=1055	70 to 79 n=724	80 to 89 n=472	90 to 99 n=32
Resistance:	522 ± 74	487 ± 63	476 ± 65	469 ± 64	470 ± 67	478 ± 71	488 ± 69	502 ± 72	525 ± 86
Reactance:	72 ± 11	74 ± 11	71 ± 11	67 ± 11	63 ± 11	60 ± 11	55 ± 11	50 ± 10	50 ± 11
Phase angle:	8.0 ± 1.0	8.7 ± 0.9	8.5 ± 0.9	8.2 ± 1.0	7.6 ± 0.9	7.1 ± 0.9	6.5 ± 1.0	5.7 ± 0.9	5.4 ± 1.2

NHANES III Females



NHANES III Females									
Age:	12 to 19 n=1448	20 to 29 n=1511	30 to 39 n=1632	40 to 49 n=1248	50 to 59 n=907	60 to 69 n=1031	70 to 79 n=817	80 to 89 n=477	90 to 99 n=44
Resistance:	622 ± 80	600 ± 83	570 ± 81	569 ± 88	566 ± 87	578 ± 88	576 ± 86	594 ± 83	612 ± 89
Reactance:	81 ± 13	82 ± 13	77 ± 12	75 ± 13	70 ± 12	68 ± 13	62 ± 12	58 ± 12	53 ± 11
Phase angle:	7.5 ± 0.9	7.8 ± 0.8	7.7 ± 0.9	7.6 ± 0.8	7.1 ± 0.9	6.7 ± 0.9	6.2 ± 1.0	5.6 ± 0.9	5.0 ± 0.7

Phase Angle Abstracts and links

Predictive value of APACHE II score is improved by

combination with bioelectrical impedance analysis in multiple trauma patients

[PHJ Mueller, et al; Critical Care 1998, 2\(Suppl 1\):P162](#)

Background: Indication to extensive critical care could be ameliorated by combining APACHE II (AP II) scores with the Phase-Angle (PA, $^{\circ}$), a global parameter of nutritional status derived from Bioelectrical Impedance Analysis (BIA). Methods: 40 (30 male/10 female) multiple trauma patients (age: 16-81 years) with a stay of >5 days on the Intensive Care Unit (ICU) were studied retrospectively. Routinely obtained daily measurements of nutritional status (BIA 101 Impedance Analyzer, RJL-Systems) included calculations of PA. Results: 10/40 patients (25%) died during ICU stay (Table). In all patients with AP II scores ≥ 20 (APACHE II-Class ≥ 5) determination of outcome would have been correct by Phase-Angle: all deceased patients had a PA < 3 , while surviving patients had a PA > 4 ($P < 0.05$). Discriminate analysis of this data reveals a probability of 100% for prediction of survival and 94% for lethal outcome respectively. Conclusion: Even in this small sample of multiple trauma patients there is a clear cutoff level of PA > 4 for prediction of survival. We suggest the routine use of BIA for observation of ICU patients, but further studies are needed to establish the prognostic relevance of this method. Predictive value of APACHE II score is improved by combination

Bioelectrical impedance phase angle in clinical practice: implications for prognosis in advanced colorectal cancer

[Gupta D, et al; American Journal Clinical Nutrition, 2004 Dec; 80\(6\):1634-8](#)

Background: Phase angle, determined by bioelectrical impedance analysis (BIA), detects changes in tissue electrical properties and has been found to be a prognostic indicator in several chronic conditions-such as HIV, liver cirrhosis, chronic obstructive pulmonary disease, and lung cancer-and in patients receiving dialysis. OBJECTIVE: This study was conducted to investigate the prognostic role of phase angle in advanced colorectal cancer. DESIGN: We evaluated a case series of 52 patients with histologically confirmed stage IV colorectal cancer. BIA was conducted on all patients and phase angle was calculated. The Kaplan-Meier method was used to calculate survival. Cox proportional hazard models were constructed to evaluate the prognostic effect of phase angle independent of other clinical and nutritional variables. RESULTS: Patients with a phase angle ≤ 5.57 had a median survival of 8.6 mo (95% CI: 4.8, 12.4; n=26), whereas those with a phase angle > 5.57 had a median survival of 40.4 mo (95% CI: 21.9, 58.8; n=26; $P=0.0001$). CONCLUSION: Phase angle is a prognostic indicator in patients with advanced colorectal cancer. Similar studies of other cancer types with larger sample sizes are needed to further validate the prognostic significance of phase angle in cancer treatment

settings.

Bioelectric impedance and individual characteristics as prognostic factors for post-operative complications.

Barbosa-Silva MC, Barros AJ; Clin Nutr. 2005 Oct;24(5):830-8.

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BACKGROUND AND AIMS: Malnutrition increases morbidity and mortality in surgical patients, and for this reason, several nutritional markers have been used as prognostic tools to identify surgical patients under a higher risk to develop complications in post-operative period. Few studies show the impact of nutritional markers after controlling for others variables, such as age and severity of disease. A new method, bioelectric impedance analysis (BIA), and its parameter, phase angle, have been described as a prognostic tool in several clinical situations, but they have never been studied in surgical population. The objective of this work is to assess the importance of nutritional variables and parameters from BIA as predictors of post-operative complications in a multivariable regression model. **METHODS:** The nutritional status of 225 adult patients scheduled to undergo gastrointestinal surgery was assessed by several methods, including bioelectric impedance analysis and subjective global assessment. Potential confounding factors were also studied. Patients were screened for post-operative complications until hospital discharge. **RESULTS:** Weight loss greater than 10%, subjective global assessment, nutritional risk assessment, ECM/BCM ratio and phase angle (from BIA) were the prognostic factors significantly associated with post-operative complications in the crude analysis. After adjusting for sex, age, marital status, tumors and pre-operative infections, only phase angle remained as a prognostic factor (RR=4.3; CI95% 1.6-11.8 for phase angle <-0.8 sd), while the other nutritional variables lost their association with post-operative complications. **CONCLUSION:** Phase angle remains as an important prognostic factor for postoperative complications, even after adjusting for other individual predictors and confounders. Its utility in the identification of patients eligible for nutritional therapy has now to be evaluated.

Bioelectrical impedance analysis in clinical practice: a new perspective on its use beyond body composition equations

[Barbosa-Silva MC, et al; Current Opinion, Clinical Nutrition Metabolic Care. 2005 May; 8\(3\):311-7](#)

PURPOSE OF REVIEW: The bioelectrical impedance analysis is not a direct method for estimating body composition. Its accuracy depends on regression

equations, and recent papers have suggested that this approach should not be used in several clinical situations. Another option is to obtain information about the electrical properties of tissues by using raw bioelectrical impedance measurements, resistance and reactance. They can be expressed as a ratio (phase angle) or as a plot (bioelectrical impedance vector analysis). This review describes their use in clinical practice. **RECENT FINDINGS:** The phase angle changes with sex and age. It is described as a prognostic tool in many clinical situations. There are some controversies about considering it as a nutritional marker. Studies in burn victims and sickle-cell disease corroborate its ability to evaluate cell membrane function. Bioelectrical impedance vector analysis allows a semi-quantitative estimation of body composition from information from tissue hydration and soft-tissue mass in a plot. It can be used in healthy individuals or patients, for a population or individual evaluation of fluid imbalance or an assessment of soft-tissue mass. It has also been used as a prognostic tool in dialysis and cancer patients. **SUMMARY:** The phase angle can be considered a global marker of health, and future studies are needed to prove its utility in intervention studies. Bioelectrical impedance vector analysis has increased its utility in clinical practice, even when the equations may be inaccurate for body composition analysis.

Bioelectrical impedance phase angle as a prognostic indicator in advanced pancreatic cancer

[Gupta D, et al; British Journal Nutrition, 2004 Dec; 92\(6\):957-62](#)

Bioelectrical impedance analysis (BIA) is an easy-to-use, non-invasive and reproducible technique to evaluate changes in body composition and nutritional status. Phase angle, determined by BIA, has been found to be a prognostic indicator in several chronic conditions, such as HIV, liver cirrhosis, chronic obstructive pulmonary disease and lung cancer, and in patients undergoing dialysis. The present study investigated the prognostic role of phase angle in advanced pancreatic cancer. We evaluated a case series of fifty-eight stage IV pancreatic cancer patients treated at Cancer Treatment Centers of America at Midwestern Regional Medical Center (Zion, IL, USA) between January 2000 and July 2003. BIA was conducted on all patients using a bioelectrical impedance analyzer that operated at 50 kHz. The phase angle was calculated as capacitance (X_c)/resistance (R) and expressed in degrees. The Kaplan-Meier method was used to calculate survival. Cox proportional hazard models were constructed to evaluate the prognostic effect of phase angle independent of other clinical and nutritional variables. The correlations between phase angle and traditional nutritional measures were evaluated using Pearson and Spearman coefficients. Patients with phase angle <5.0 degrees had a median survival time of 6.3 (95% CI 3.5, 9.2) months (n 29), while those with phase angle >5.0 degrees had a median survival time of 10.2 (95% CI 9.6, 10.8) months (n 29); this difference was statistically significant ($P=0.02$). The present study

demonstrates that phase angle is a strong prognostic indicator in advanced pancreatic cancer. Similar studies in other cancer settings with larger sample sizes are needed to further validate the prognostic significance of the phase angle.

Norms and correlates of bioimpedance phase angle in healthy human subjects, hospitalized patients, and patients with liver cirrhosis

[Selberg O, European Journal of Applied Physiology, 2002 Apr; 86\(6\):509-16](#)

This study investigates whether bioimpedance indexes rather than derived body compartments would be adequate for nutritional assessment. Evidence is provided that the phase angle as determined by conventional tetrapolar whole body bioelectrical impedance analysis at 50 kHz (1) was largely determined by the arms and legs and not the trunk, (2) was higher in control subjects than in hospitalized patients [mean (SD) 6.6 degrees (0.6) degrees vs 4.9 degrees (1.2) degrees, $P < 0.001$], (3) discriminated poorly between cirrhotic patients of different Child-Pugh class, and (4) was positively correlated with muscle mass ($r = 0.53$) and muscle strength ($r = 0.53$) in these patients (each $P < 0.01$). In a prospective study of patients with liver cirrhosis Kaplan-Meier and log rank analyses of survival curves demonstrated that patients with phase angles equal to or less than 5.4 degrees had shorter survival times than patients with higher phase angles [6.6 degrees (1.4) degrees] and that phase angles less than 4.4 degrees were associated with even shorter survival times ($P < 0.01$). The prognostic roles of the phase angle and standard nutritional parameters such as total body potassium, anthropometric measurements, and impedance derived fat free mass, body cell mass and fat mass were evaluated separately by Cox regression which eliminated all variables except the phase angle as predictors of patient survival time ($P < 0.01$). We concluded that for the clinical assessment of patients the phase angle may be superior to commonly used body composition information.

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

[Mushnick R, et al; Kidney International Supplement, 2003 Nov; \(87\):S53-6](#)

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 pre-albumin. Patients were followed until April 2003. RESULTS: The mean age of PD patients was 51 +/- 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 +/- 5.0 kg/m². Mean resistance, reactance, and phase angle were 521 +/- 104 ohms, 57 +/- 19 ohms, and 6.16 +/- 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 pre-albumin 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 pre-albumin and BIA parameters in the regular assessment of PD patients, whose survival may be improved by better management of malnutrition and overall health status.

The validity of bioelectrical impedance phase angle for nutritional assessment in children

[Nagano M, et al; J Pediatric Surgery, 2000 Jul; 35\(7\):1035-9](#)

BACKGROUND/PURPOSE: Bioelectrical impedance analysis (BIA) is a quick and noninvasive method for estimating body composition. Many prediction equations have been reported recently using bioelectrical impedance to calculate fat free mass (FFM) and fat mass (FM). These equations are based on the assumption that the composition and density of FFM are stable. In children, the composition and density of FFM vary according to age and clinical state, so the use of these equations is limited. However, phase angle is directly determined from resistance (R_z) and reactance (X_c) without equations and reflects body cell mass. The authors, therefore, investigated the validity of phase angle for nutritional assessment in children. METHODS: Bioelectrical impedance analysis and anthropometric measurements were performed in 81 patients, including 71 well-nourished and 10 malnourished children. RESULTS: Phase angle correlated with body weight (R = 0.818) and arm muscle circumference (r = 0.901) in well-nourished children. Malnourished patients showed lower phase angle than that of well-nourished children. CONCLUSION: Bioelectrical impedance phase angle is a useful parameter for nutritional assessment in children.

Changes in bioimpedance analysis after stable refeeding of undernourished anorexic patients

[Scalfi L, et al; International Journal Obesity Related Metabolic Disorders, 1999 Feb; 23\(2\):133-7](#)

OBJECTIVE: To evaluate bioimpedance analysis (BIA) parameters in patients with anorexia nervosa when undernourished and then after stable refeeding.

DESIGN: Follow-up study. **SUBJECTS:** Thirteen patients with anorexia nervosa who were studied when undernourished (body weight (Wt): 36.9+/-5.6kg, body mass index (BMI): 14.8+/-1.8kg/m²) and after stable refeeding (Wt: 52.9+/- 7.1kg, BMI: 21.2+/-2.3 kg/m²) compared to 25 well-nourished control women (Wt: 53.7+/-4.9 kg, BMI: 21.1+/-1.3 kg/m²).

MEASUREMENTS: Impedance and phase angle were determined for the whole body (13 patients) and separately for arms and legs (10 patients).

RESULTS: Bioimpedance index (height²/impedance) and phase angle were lower in the undernourished group. Whole-body impedance declined (median, min-max) by 45, 1-151 Ohm after refeeding; the variations of bioimpedance index (BI-Index) were weakly correlated ($P < 0.10$) with BMI changes. Limb phase angles increased with refeeding, but only changes in whole-body phase angle were correlated ($P < 0.025$) with the corresponding variations of Wt or BMI.

CONCLUSION: Whole-body phase angle increased after weight recovery of anorexic patients, suggesting the occurrence of modifications in the extracellular-to- intracellular water ratio. These changes were proportional to the increase in BMI and Wt.

Altered tissue electric properties in lung cancer patients as detected by bioelectric impedance vector analysis

[Toso S, et al; Nutrition, 2000 Feb; 16\(2\):120-4](#)

Modifications of body composition are frequent in cancer patients. Bioelectric impedance analysis can specifically detect changes in tissue electric properties, which may be associated with outcome. We evaluated the distribution of the impedance vectors from 63 adult male patients with lung cancer, stages IIIB (33 patients) and IV (30 patients), in supportive therapy. Body weight change over the previous 6 mo. was the same in both groups (stable/increased 36% and decreased in 62%). Patients were compared with 56 healthy subjects matched for gender, age, and body mass index (25 kg/m²). Impedance measurements (standard tetrapolar electrode placement on the hand and foot) were made with 50-kHz alternating currents. The resistance and reactance of the vector components were standardized by the height of the subjects and were plotted as resistance/reactance graphs. The impedance vector distribution was the same in patients with either stage IIIB or IV cancer. The mean vector position differed significantly between cancer patients and control subjects (Hotelling T² test, $P <$

0.01) because of a reduced reactance component (i.e., a smaller phase angle) with preserved resistance component in both cancer groups. Patients with a phase angle smaller than 4.5 degrees had a significantly shorter, i.e., 18 mo., survival. Body weight loss was not significantly associated with survival. In conclusion, impedance vectors from lung cancer patients were characterized by a reduced reactance component. The altered tissue electric properties were more predictive than weight loss of prognosis.

Phase angle is a predictor of basal metabolic rate in female patients with anorexia nervosa

[Marra M, et al; *Physiology Measurement*, 2005 Apr; 26\(2\):S145-52](#)

The aim of the study was to evaluate the relationship between basal metabolic rate (BMR) and bioelectrical impedance analysis (BIA) in undernourished female patients with anorexia nervosa. Participants were 86 female patients with anorexia nervosa (age 20.8 +/- 4.7 years; weight 39.3 +/- 5.2 kg; body mass index 15.4 +/- 1.6 kg m⁻²). BMR was measured by indirect calorimetry and single-frequency BIA was determined at 50 kHz on the whole body. The BIA variables considered were resistance, reactance, phase angle and the bioimpedance index (height²/resistance). Fat-free mass was calculated from subcutaneous skin fold thickness. In the study group BMR was 3782 +/- 661 kJ d⁻¹ while bioimpedance index varied between 27.6 and 49.9 cm² Omega⁻¹ and phase angle between 2.54 degrees and 6.49 degrees. BMR was significantly correlated with weight, height, body mass index and fat-free mass, and, among BIA variables, with reactance and phase angle. Multiple regression analysis indicated that phase angle was a predictor of BMR not only when solely BIA variables were considered, but also in combination with either weight or age or fat-free mass. In conclusion, phase angle emerged as a strong predictor of BMR in female patients with anorexia nervosa. Nevertheless, further studies are necessary to confirm this finding in other forms of protein energy malnutrition and justify the inclusion of BIA variables in the equations used to predict BMR in the clinical setting.

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

[Michael Ott, Harold Fischer; et al; *Journal of Acquired Immune Deficiency Syndromes and Human Retrovirology* 9:20-25 1995](#)

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 \emptyset , extracellular mass (ECM), body cell mass (BCM) measured by bioelectrical impedance analysis), of the CD4+ cell count, 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 \emptyset (parameter estimate: 1.043, 95% confidence interval of 0.61 to 1.47) $P < 0.0001$ 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 CD4+ cells, phase angle, pentamidine, azidothymidine, the prognostic impact of the CD4+ cell count (parameter estimate: - 0.549) was lower compared with the phase angle \emptyset (parameter estimate: - 0.799); ($P < 0.0001$) and did not gain statistical significance ($P = 0.0626$). The phase angle \emptyset 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 by the phase angle \emptyset is a major determinant of long term survival in HIV infection, thereby representing an important parameter for monitoring disease progression.

Bioelectrical Impedance Analysis Predicts Survival in Hemodialysis Patients

*G.M Chertow, et al; Renal Division, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, **Published as "BLUE RIBBON AWARD" Abstract # T164, A0969, page 1442, journal of the American Society of Nephrology, September 1996, Volume 7, #9 Link not available*

Abstract: We performed a cross-sectional study of BIA (Bioelectrical impedance analysis, BIA 101-Q, RJL Systems, Clinton Township, MI) in 3009 HD (hemodialysis) patients with follow-up to 12 (median 8) months to evaluate the relation between impedance and survival. 296 deaths were documented over the study period; patients were censored at transplantation or if lost to follow-up. Mean (\pm SD) age was 60.5 ± 15.5 years, 47% were females, 47% African-American, and 36% diabetic. Dialysis vintage was 3.8 ± 3.7 years. Mean reactance (Xc) was 40.9 ± 13.8 ohms; mean resistance (R) was 497.7 ± 99.0 ohms. The mean Xc/R ratio 0.084 ± 0.030 ; Xc/R was directly correlated with albumin ($r=0.24$), pre-albumin ($r=0.27$), and creatinine ($r=0.40$), and inversely correlated with age ($r= -0.33$) and Quartile's index ($r= - 0.15$). Xc/R was significantly higher in men Africa Americans, and non-diabetics ($P < 0.0001$ compared with women, Caucasians, and diabetics, respectively). To obviate linearity assumptions, Xc/R was ranked into quintiles, and the relative risks of death (RR) and 95% confidence intervals (95% CI) within each quintile were estimated from proportional hazards regression, with and without covariate

adjustment. Survival in patients within the upper three quintiles of Xc/R; The RR in the two lowest quintiles was 2.7 (95% CI 1.1 to 2.2, P=0.009), respectively. After adjustment for age, sex, race, diabetes, albumin, creatinine, and urea reduction ratio, the RR in the lowest quintile was 1.5 (95% CI 1.2 to 2.1, P=0.003). Results were similar when Xc and R were adjusted for body stature. Conclusion: Xc/R is correlated with biochemical surrogates of nutritional status in hemodialysis patients, and provides prognostic power even after adjustment for case mix and laboratory variables. Longer-term follow-up and longitudinal assessment of Xc/R will be required to determine the optimal role for BIA in HD patient assessment.

Phase angle from bioelectrical impedance analysis remains an independent predictive marker in HIV-infected patients in the era of highly active antiretroviral treatment

[Schwenk A, et al; American Journal of Clinical Nutrition, 2000 Aug; 72\(2\):496-501](#)

Abstract: BACKGROUND: Highly active antiretroviral treatment (HAART) reduces the risk of wasting in HIV infection and may alter the prognostic weight of wasting. The phase angle from bioelectrical impedance analysis (BIA) can be interpreted as a surrogate marker for the catabolic reaction to chronic HIV infection and opportunistic disease. OBJECTIVE: Our objective was to assess the prognostic ability of the phase angle in HIV- infected patients in the era of HAART. DESIGN: Two cross- sectional observation studies were conducted in 1996 and 1997 at a German university outpatient HIV clinic. In the 1996 and 1997 cohorts, HAART was prescribed to 17 of 212 and 168 of 257 patients at baseline and to 179 of 212 and 234 of 257 patients during observation, respectively. Whole-body BIA was assessed at 50 KHz. Time to clinical progression and survival were calculated by using Cox proportional hazard models with time-dependent covariates. Median observation times were 1000 and 515 d for the 1996 and 1997 cohorts, respectively. RESULTS: Higher phase angle was associated with a lower relative mortality risk, adjusted for viral load and CD4+ cell count, of 0.49 (95% CI: 0.30, 0.81) per degree in 1996 and of 0.33 (95% CI: 0.18, 0.61) in 1997. The influence of phase angle on time to clinical progression, adjusted for viral load and CD4+ cell count, was not significant in 1996 but the relative risk was 0.58 (0.36, 0.83) in 1997. CONCLUSION: Despite the favorable effects of HAART on the nutritional status of HIV-infected persons, low phase angle remains an independent adverse prognostic marker of clinical progression and survival.

Bioelectrical impedance analysis for assessment of severity of illness in pediatric patients after heart surgery

[Shime N, et al; Critical Care Medicine 2002 Mar; 30\(3\):518-20](#)

OBJECTIVE: To investigate whether perioperative changes in bioelectrical impedance reflect the severity of illness in pediatric patients after heart surgery. **DESIGN:** Prospective, controlled study. **SETTING:** University-affiliated children's hospital. **PATIENTS:** A total of 107 patients admitted to a pediatric intensive care unit after congenital heart surgery. **INTERVENTIONS:** None. **MEASUREMENTS AND MAIN RESULTS:** Single frequency (50 kHz) bioelectrical impedance was measured in the lower extremities before surgery and immediately, 16 hrs, and 40 hrs after admission (D0, D1, D2) to the pediatric intensive care unit. Postoperative changes in bioelectrical impedance were assessed by calculating values relative to the preoperative data (bioelectrical impedance ratio). These bioelectrical impedance ratios at D0 in both the nonsurviving and surviving patients were 0.84 ± 0.06 and 0.85 ± 0.01 (mean \pm SE), respectively, indicating that the initial decrease caused by surgical stress itself was not directly related to the prognosis. The bioelectrical impedance ratio showed an increase toward preoperative values in surviving patients (0.94 ± 0.02) at D1, and they showed a sustained decrease (0.70 ± 0.06) in nonsurviving patients. Patients with a bioelectrical impedance ratio at D1 of < 0.8 showed a higher mortality (25%) compared with those patients with a day-1 bioelectrical impedance ratio of ≥ 1.0 (0%). The duration of the stay in the pediatric intensive care unit, mechanical ventilation, and inotropic support were all significantly longer in the patients with the lower bioelectrical impedance ratio. **CONCLUSIONS:** Measurement of the relative changes in postoperative bioelectrical impedance, which reflects perioperative alterations in body composition, provides a quantitative estimation of the critical illness in pediatric patients after heart surgery.

Localized bioimpedance analysis in the evaluation of neuromuscular disease

[Rutkove SB, Muscle Nerve 2002 Mar; 25\(3\):390-7](#)

Localized bioimpedance analysis is a novel, noninvasive technique with potential application to neuromuscular disease. In this procedure, high-frequency alternating current is passed through muscle, and parameters related to the consequent voltage pattern are evaluated. Currents flowing perpendicular to muscle fibers encounter many more cell membranes than do currents flowing parallel to them, producing surface voltage patterns that are altered by disease. Using this technique, 45 normal subjects and 25 patients with various neuromuscular diseases were studied, including 4 with amyotrophic lateral sclerosis, 4 with inflammatory myopathy, and 11 with inclusion-body myositis. Two parameters, the spatially averaged phase and the effective longitudinal resistivity, were altered in patients with neuromuscular disease. Reductions in phase correlated to disease progression, whereas normalization of phase

correlated with disease remission. In patients with inclusion-body myositis, a unique pattern of reduced phase and elevated resistivity was identified. These findings suggest that localized bioimpedance analysis has the potential of playing a substantial role in the diagnostic and therapeutic evaluation of neuromuscular disease.

Bioelectrical impedance analysis: population reference values for phase angle by age and sex

[Maria Cristina G Barbosa-Silva, et al; American Journal of Clinical Nutrition, Vol. 82, No. 1, 49-52, July 2005](#)

BACKGROUND: Phase angle is an indicator based on reactance and resistance obtained from bioelectrical impedance analysis (BIA). Although its biological meaning is still not clear, phase angle appears to have an important prognostic role. **OBJECTIVE:** The aim of this study was to estimate population averages and SDs of phase angle that can be used as reference values. **DESIGN:** BIA and other methods used to evaluate body composition, including hydrodensitometry and total body water, were completed in 1967 healthy adults aged 18-94 y. Phase angle was calculated directly from body resistance and reactance, and fat mass (FM) was estimated from the combination of weight, hydrodensitometry, and total body water by using the 3-compartment Siri equation. Phase angle values were compared across categories of sex, age, body mass index (BMI), and percentage FM. **RESULTS:** Phase angle was significantly ($P < 0.001$) smaller in women than in men and was lower with greater age ($P < 0.001$). Phase angle increased with an increase in BMI and was significantly inversely associated with percentage fat in men. Phase angle was significantly predicted from sex, age, BMI, and percentage FM in multiple regression models. **CONCLUSIONS:** Phase angle differs across categories of sex, age, BMI, and percentage fat. These reference values can serve as a basis for phase angle evaluations in the clinical setting.