

Applied nutritional investigation

# Is bioelectrical impedance vector analysis of value in the elderly with malnutrition and impaired functionality?

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Manuscript received March 17, 2007; accepted May 22, 2007.

## Abstract

**Objective:** The calculation of body composition using bioelectrical impedance analysis is difficult in the elderly because most equations have been found to be inadequate, especially in the malnourished elderly. We therefore evaluated the use of bioelectrical impedance vector analysis in elderly nursing home residents.

**Methods:** One hundred twelve nursing home residents were included in the study (34 men, 78 women, age 85.1 y, age range 79.1–91.4 y). Nutritional status was determined by the Mini Nutritional Assessment (MNA), functional status was assessed by handgrip strength, knee extension strength, and Barthel's index, and bioelectrical impedance analysis was performed using Nutriguard M (Data Input, Darmstadt, Germany).

**Results:** Twenty-two nursing home residents were classified as well nourished (MNA I), 80 were considered to be at nutritional risk (MNA II), and 10 were classified as malnourished (MNA III). Handgrip strength, knee extension strength, and Barthel's index were lower in MNA II and MNA III than in MNA I. Phase angle also decreased significantly with the MNA (4.0, 3.8–4.7°; 3.7, 3.3–4.3°; and 2.9, 2.6–3.5°). There was a significant displacement of the mean vector in MNA II and MNA III compared with MNA I.

**Conclusion:** The bioelectrical impedance vector analysis resistance/reactance graph could represent a valuable tool to assess changes in body cell mass and hydration status in elderly nursing home residents. © 2007 Elsevier Inc. All rights reserved.

## Keywords:

Bioelectrical impedance vector analysis; Nursing home residents; Impaired nutritional and functional status; Mini Nutritional Assessment status

## Introduction

Many studies have shown that nutritional status is frequently impaired in the institutionalized or frail elderly [1,2]. Malnutrition is associated with changes of body composition and functional status, and significant losses of fat free or muscle mass might already occur when body weight is still normal [3].

Routine body composition analysis is hampered in this population due to, e.g., very cumbersome methods such as dual-energy x-ray absorptiometry, densitometry, or total

body potassium counting. Furthermore, there is a lack of adequate reference data for old and very old people.

When using simpler methods such as bioelectrical impedance analysis (BIA), most equations for the calculation of body compartments using impedance parameters at 50 kHz have been found to be inadequate in the elderly, especially in the undernourished elderly [4,5]. However, BIA is easy to use, inexpensive, and non-invasive, which renders it a safe and attractive bedside method, especially for elderly and bedridden subjects.

The raw impedance parameters, resistance (R) and reactance (Xc) and the phase angle obtained by the BIA, provide information about tissue hydration and cell integrity through the electrical tissue properties. Xc is the resistive effect produced by the tissue interfaces and cell membranes to the flow of an alternating electric current, whereas bioelectric R

The study was funded by a grant from Schubert Holding AG & Co. KG.  
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is the pure opposition of a biological conductor. The phase angle reflects the contributions between R and capacitance (arc tangent of the ratio of capacitance to R transformed to degrees). Xc values and phase angle have been shown to be of prognostic importance in many disease settings by predicting survival in the perioperative setting and in cancer or human immunodeficiency viral infection [6–10].

Recently, bioelectrical impedance vector analysis (BIVA), where the R and Xc obtained at 50 kHz and normalized per height (H) are plotted as a bivariate vector, has gained attention as a valuable tool to assess patients' hydration status and cell mass, because it is independent from regression equations and body weight [11–13].

However, little is known about these raw impedance parameters or the vector analysis in the institutionalized elderly and whether these are useful in indicating alterations in body composition.

We determined the nutritional and functional status in elderly nursing home residents by using the Mini Nutritional Assessment (MNA), muscle function tests, and Barthel's index. We specifically wanted to investigate the association between nutritional status and impedance parameters obtained by BIA and to study the mean vector displacement of the MNA groups on the RXc graph.

## Materials and methods

### Patients

We included 112 elderly institutionalized subjects (34 men, 78 women, age 85.1 y, age range 79.1–91.4 y). The main exclusion criterion was severe dementia. Implanted defibrillators were considered further exclusion criteria for the BIA and individuals with hemiplegia or severe arthritis were excluded to avoid potential confounders on muscle strength. All study participants gave written informed consent and the ethics committee of the Charité-University Medicine Berlin approved the study. All study participants were Caucasians.

### Nutritional status

Nutritional status was determined with the MNA as described by Vellas et al. [14]. Patients were characterized as well nourished (>23.5 points; MNA I), at nutritional risk (17–23.5 points; MNA II), or severely malnourished (<17 points; MNA III).

### Whole-body impedance measurement

Bioelectrical impedance analysis was performed using Nutriguard M (Data Input GmbH, Darmstadt, Germany) and applying alternating electric currents of 800  $\mu$ A at 50 kHz and the R and Xc were measured.

Patients were measured in the morning after an overnight

fast, in the supine position with arms and legs abducted from the body. Source and sensor electrodes (silver/silver chloride, Bionostic Classic Electrodes, Data Input) were placed on the dorsum of the hand and foot of the dominant side of the body.

The coefficient of variance of repeated measurements of R and Xc at 50 kHz was assessed in four elderly residents: The coefficients of variance were 1.2 for R and 2.5 for Xc.

### Vectograph

Bioelectric impedance vector analysis uses the plot of direct measurements of the vector components R and Xc. According to the RXc graph, R and Xc normalized for body H are plotted as a bivariate random vector (Xc/H versus R/H) on the RXc plane. The vector distribution is described by its associated 95% confidence interval (confidence ellipse in the RXc plane). The shortening or lengthening of the vector indicates hydration status in the form of edema or dehydration, respectively, whereas a migration sideways indicates an increase or a decrease in body cell mass [15].

### Muscle function

Handgrip strength was measured in the non-dominant hand with a Digimax electronic dynamometer (Mechatronic Hamm GmbH, Germany). The study participants performed the test while sitting comfortably with the shoulder adducted and neutrally rotated, the elbow supported on a table and flexed to 90 degrees, and the forearm and wrist in a neutral position. The study participants were instructed to perform a maximal isometric contraction. The test was repeated twice within 30 s and the highest value of the three measurements was recorded.

Knee extension strength was measured while the study participants were seated, with the legs not touching the floor. The right leg was then fixed with a sling that was connected to the wall behind the study participants and connected with a force sensor. Patients were then encouraged to perform maximum knee extension. The test was repeated twice and the highest value of the three measurements was recorded.

Peak expiratory flow was assessed with the Assess Peak Flow Meter (CE Respironics, Health Scan, NJ, USA). Study participants were told to exhale as quickly and forcefully as possible. The test was carried out three times and the highest reading was recorded.

### Barthel's index

Barthel's index of activities of daily living is an instrument to systematically evaluate the functional status of older adults as the individual's ability to independently perform basic activities of daily living is measured. Subjects reaching 100 points on the index will be able to care for

Table 1  
Demographic and nutritional characteristics of the study population\*

	MNA I	MNA II	MNA III
Age (y)	84.0 (74.4–91.3)	85.2 (79.5–91.4)	87.6 (80.6–92.1)
Subjects (male/female)	22 (11/11)	80 (22/58)	10 (1/9)
Weight (kg)	68.6 (63.9–81.9) <sup>a§</sup>	59.5 (53.0–67.7) <sup>b§</sup>	43.5 (35.4–52.4) <sup>c§</sup>
Height (m)	1.64 (1.60–1.72)	1.61 (1.58–1.68)	1.59 (1.52–1.65)
BMI (kg/m <sup>2</sup> )	25.6 (23.0–30.2) <sup>a§</sup>	22.6 (20.1–24.9) <sup>b‡</sup>	16.8 (15.4–20.2) <sup>c§</sup>
R/H ( $\omega$ /m)	287.1 (265.5–329.8) <sup>a†</sup>	352.5 (299.8–385.4)	372.0 (337.0–455.4) <sup>c†</sup>
Xc/H ( $\omega$ /m)	21.2 (18.8–23.0)	21.5 (18.1–26.3)	19.3 (17.8–22.6)
Phase angle (°)	4.0 (3.8–4.7) <sup>a†</sup>	3.7 (3.3–4.3) <sup>b†</sup>	2.9 (2.6–3.5) <sup>c‡</sup>
Barthel's index (%)	80.0 (45.0–91.3)	65.0 (31.3–80.0)	22.5 (8.8–76.3) <sup>c†</sup>
Handgrip strength (kg)	16.3 (11.8–21.4)	13.7 (8.5–18.0) <sup>b†</sup>	6.3 (3.6–10.8) <sup>c‡</sup>
Knee extension strength (kg)	10.3 (7.3–16.4) <sup>a†</sup>	8.0 (5.0–12.0)	5.0 (3.0–7.0) <sup>c†</sup>
Peak flow (L/min)	205.0 (150.0–280.0) <sup>a†</sup>	160.0 (108.8–241.3)	100.0 (75.0–135.0) <sup>c†</sup>

BMI, body mass index; MNA, Mini Nutritional Assessment; R/H, resistance normalized per height; Xc/H, reactance normalized per height

\* Median (interquartile range). Significance between <sup>a</sup>I and II, <sup>b</sup>II and III, and <sup>c</sup>I and III.

†  $P < 0.05$ .

‡  $P < 0.01$ .

§  $P < 0.001$ .

themselves but might still need help in certain situations. A person with 0 point is completely dependent [16].

### Statistics

Statistical analysis was carried out using SPSS 13 (SPSS Inc., Chicago, IL, USA).

All data are presented as median and interquartile range. Multiple comparisons among the three MNA groups were performed by the Kruskal-Wallis test, and in case of significance the Mann-Whitney U test was used for comparison between groups. Spearman's correlation was calculated to assess the relation between variables.

Statistically significant differences between the mean vectors of the MNA groups were assessed with Hotelling's  $T^2$  test for vector analysis. Mahalanobis distance,  $D$ , a generalized measurement of distance between groups defined by two correlated variables, was also calculated. Vector analysis was performed with BIVA software (Department of Medical and Surgical Sciences, University of Padova, Padova, Italy, 2002).

An acceptable level of statistical significance was established a priori at  $P < 0.05$ .

### Results

Of the 112 participating residents, 22 (19.6%) were classified as well nourished, 80 (71.4%) were classified as at nutritional risk, and 10 (8.9%) were classified as malnourished.

Demographic data and data on impedance and anthropometric parameters, muscle function, and Barthel's index according to the MNA groups are listed in Table 1. There were no significant differences among the three MNA categories regarding age. According to the World Health Or-

ganization classification, the median body mass index (BMI) of the well-nourished patients was classified as overweight, whereas body weight and BMI were significantly decreased in MNA groups II and III.

### Functional status

As anticipated, nutritional status was closely correlated with functional status: malnourished elderly (MNA III) had a significantly weaker handgrip strength than did well-nourished elderly (MNA I) or subjects classified at risk for malnutrition (MNA II; Table 1). Similarly, knee extension strength and peak flow were lower in MNA III and MNA II than in MNA I subjects. Barthel's index, an overall measurement of functional ability, was significantly lower in MNA III than in MNA I subjects.

### Bioelectrical impedance measurements

Phase angle was significantly smaller in the MNA II than in the MNA I group and decreased further in the MNA III group (Fig. 1).

We obtained significant correlations between phase angle and the muscle function parameters handgrip strength and knee extension strength, as shown in Figure 2. Furthermore, there was a significant correlation between phase angle and Barthel's index ( $r = 0.395$ ,  $P < 0.0001$ ).

The R and Xc values normalized per height are presented in Table 1, and as shown in Figure 3, there was a significant vector displacement of the mean impedance vector in groups MNA II and MNA III compared with group MNA I as can be seen by the separate 95% confidence limits due to significantly increased R/H values with comparable Xc/H values.

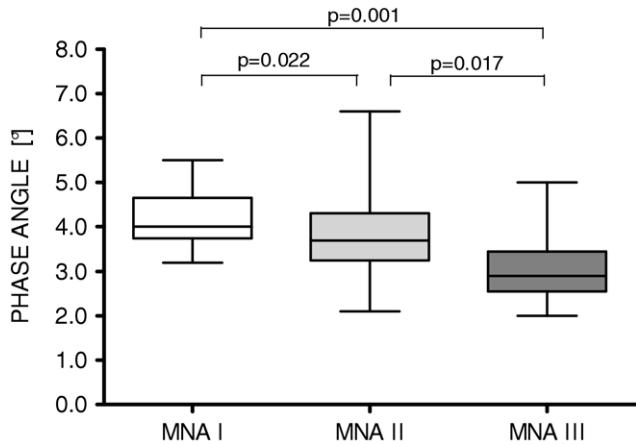


Fig. 1. Significantly smaller phase angle in malnourished elderly (MNA III) and elderly at risk of malnutrition (MNA II) compared with well-nourished subjects (MNA I). MNA, Mini Nutritional Assessment.

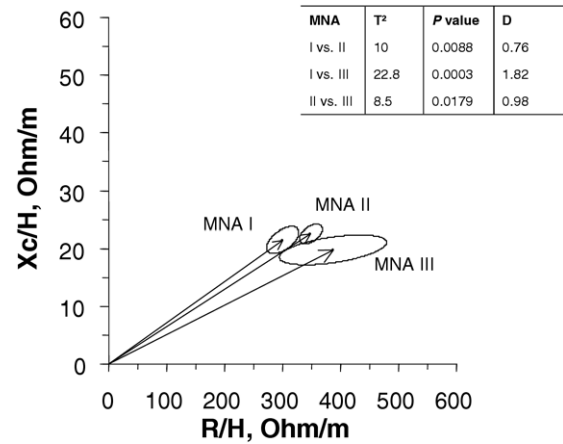


Fig. 3. Significant mean vector displacement across MNA groups: MNA I, well nourished ( $n = 22$ ); MNA II, at nutritional risk ( $n = 80$ ); MNA III, malnourished ( $n = 10$ ).  $D$ , Mahalanobis distance between two groups defined by the two correlated variables; MNA, Mini Nutritional Assessment;  $R/H$ , resistance normalized per height;  $T^2$ , Hotelling's  $T^2$  statistic;  $Xc/H$ , reactance normalized per height.

**Discussion**

In our study population, malnutrition classified by the validated MNA questionnaire was shown to be associated with functional impairment as seen by the significantly decreased Barthel's index and muscle function. Moreover, the phase angle was significantly smaller in the residents at nutritional risk and even further decreased in malnourished subjects. The phase angle has been shown to be predictive of poor survival in lung, pancreatic, and colorectal cancer and in patients with benign diseases such as liver cirrhosis [17], chronic obstructive pulmonary disease [18], human immunodeficiency viral infection [8,9], and in patients using hemodialysis [19].

Thus, the results of our study clearly show that clinically diagnosed malnutrition is associated with prognostically relevant changes of whole-body electrical tissue properties. Moreover, the phase angle correlated significantly with the muscle function parameters handgrip strength and knee ex-

tension in our study population of elderly nursing home residents.

Because malnutrition is known to decrease muscle function and body cell mass [3], these findings per se are not surprising. However, age, which is known as one of the most influential factors on phase angle and muscle function, was not different between well-nourished and malnourished subjects or those at nutritional risk.

However, when studying the three MNA groups on the vectograph, it appears that the decrease of the phase angle in this study population is due to an increased  $R$  between groups MNA I and II, indicating an alteration in hydration status, with a similar  $Xc$ , suggesting comparable proportional cell mass across groups, whereas it is due to increased  $R$  and decreased  $Xc$  between groups MNA II and III.

Several factors are known to influence the vector position on the  $RXc$  graph such as age, gender, and ethnic origin

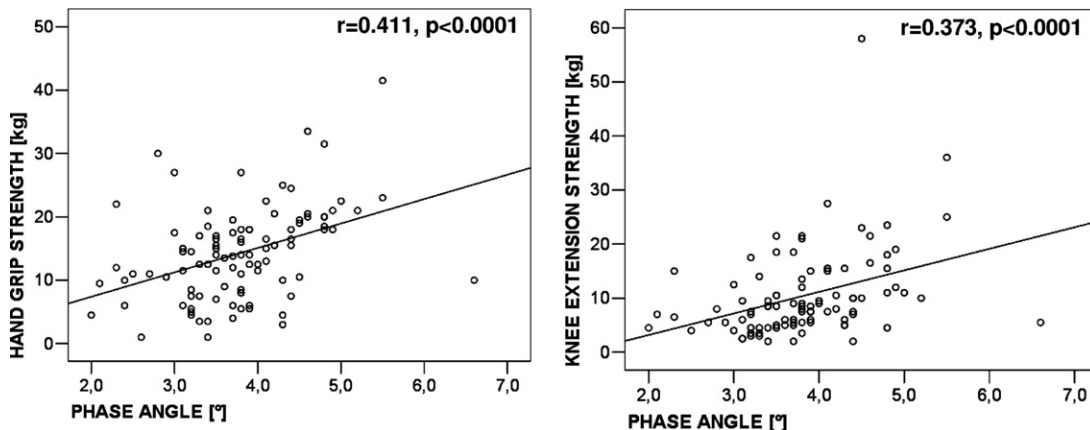


Fig. 2. Significant correlations between phase angle and (left) handgrip strength and (right) knee extension strength in the entire study population ( $n = 112$ )

[14,19]. Whereas the higher prevalence of male gender in group MNA I might, e.g., contribute to shortening the mean vector, older age, which modestly lowers the Xc component for any BMI class [20], was not different across the three MNA groups and therefore did not likely affect the Xc component.

The vector migration has also been shown to be dependent on BMI [15,21], because an increase in BMI causes a proportional decrease in R and Xc in healthy subjects [21]. As BMI decreases significantly with the MNA in our study population, an influence on the components R and Xc would be expected and was also observed between groups MNA I and II, indicating a preserved soft tissue mass for a given BMI class.

If the BMI were also the main influencing factor on the vector of the MNA III, then higher Xc values would have been expected according to these BIVA patterns. However, we observed a decreased Xc for the given R, implying less cell mass than anticipated (i.e., an abnormal soft tissue structure) in the patients considered severely malnourished.

It is clear that other factors than the BMI such as sickness and catabolism have a profound effect on cell mass and structure in the elderly classified as malnourished by the MNA.

Bioelectrical vector analysis ultimately provides more detailed information on nutritional and hydration statuses in the elderly than the phase angle alone.

Limitations of our study are the different sample sizes of the MNA groups and the gender distribution, but which represent the demographic distribution of the nursing home population.

Monitoring body weight alone might not prove sufficient for the evaluation of nutritional status in the elderly, because it does not disclose alterations of body composition. Also, the correlations between BMI and fat mass are no longer as strong in the elderly as these are in younger people [22]. Methods allowing an easy monitoring of nutritional status in the elderly are therefore attractive. BIA is considered a reliable tool for body compartment calculation in healthy individuals with no fluid imbalance, body shape abnormalities, within a certain BMI range (16–34 kg/m<sup>2</sup>), and when appropriate, i.e., when gender- and age-specific equations are applied [23]. However, these conditions are frequently not present in elderly institutionalized individuals due to a higher interindividual variation of fat-free mass hydration and a higher occurrence of polymorbidity. Therefore, we did not calculate body cell mass or fat-free mass in our study population because equations for predicting body composition using bioelectrical impedance are not adequate in the elderly, particularly not in malnourished elderly [5,24].

The main advantages of BIVA, its independence of body weight or equation-inherent errors, render it an attractive alternative method. Information about tissue hydration and cell mass and integrity in the elderly can be gained from the BIVA. BIVA could represent a valuable tool for the mon-

itoring of the nutritional and functional statuses after an initial assessment, especially in elderly, demented, or bedridden subjects.

However, to use the BIVA or the phase angle as sole indicators for nutritional and functional status, reference data for old and very old subjects are required, providing cutoff values.

In conclusion, impaired nutritional and functional status are common in elderly nursing home residents. Simple bedside methods are required. BIVA represents an interesting tool for monitoring nutritional and functional status in the institutionalized elderly.

### Acknowledgments

The authors thank A. Piccoli and G. Pastori (BIVA software, Department of Medical and Surgical Sciences, University of Padova, Padova, Italy 2002) for kindly providing the freely available BIVA software.

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