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Dynamic changes in bioelectrical impedance vector analysis and phase angle in acute decompensated heart failure

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ABSTRACT

Objectives: To evaluate whether changes in hydration status (reflecting fluid retention) would be detected by bioelectrical impedance vector analysis (BIVA) and phase angle during hospitalization for acute decompensated heart failure (ADHF) and after clinical stabilization.
Methods: Patients admitted to ADHF were evaluated at admission, discharge and after clinical stabilization (3 mo after discharge) for dyspnea, weight, brain natriuretic peptide, bioelectrical impedance resistance, reactance, and phase angle. Generalized estimating equations and chi-square detected variations among the three time points of evaluation.
Results: Were included 57 patients: Mean age was 61 ± 13 y, 65% were male, LVEF was 25 ± 8%. During hospitalization there were improvements in clinical parameters and increase in resistance/height (from 250 ± 72 to 302 ± 59 Ohms/m, $P < 0.001$), reactance/height (from 24 ± 10 to 31 ± 9 Ohms/m, $P < 0.001$), and phase angle (from 5.3 ± 1.6 to 6 ± 1.6°, $P = 0.007$). From discharge to chronic stability, both clinical and BIVA parameters remained stable. At admission, 61% of patients had significant congestion by BIVA, and they lost more weight and had higher improvement in dyspnea during hospitalization ($P < 0.05$). At discharge, more patients were in the upper half of the graph (characterizing some degree of dehydration) while at chronic stability normal hydration status was more prevalent ($P < 0.001$).
Conclusions: BIVA and phase angle were able to detect significant changes in hydration status during ADHF, which paralleled the clinical course of recompensation, both acutely and chronically. The classification of congestion by BIVA at admission identified patients with more pronounced changes in weight and dyspnea during compensation.

Introduction

Acute decompensated heart failure (ADHF), the rapid onset or worsening of symptoms and signs of heart failure, is a life-threatening condition that requires immediate medical attention and usually leads to urgent hospital admission [1]. Episodes of ADHF may be associated with changes in nutritional status and body composition parameters [2], mainly related to congestion. The evaluation of body composition in ADHF is challenging in clinical practice because several methods, validated in other scenarios, are influenced by changes in hydration status [3,4]. On the other hand, volume overload can be present even in the absence of peripheral edema or pulmonary congestion; therefore, one might erroneously rule out the presence of congestion if only physical examination findings are considered [5].

Bioelectrical impedance vector analysis (BIVA) has been used in conditions that feature altered hydration status [6]. It uses the electrical properties of tissues, as quantified by raw measurements of bioelectrical impedance, resistance and reactance, normalized by the subject's height, and compared against the values of a reference population plotted on a graph. The relationship between resistance and reactance is known as the phase

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angle. Increased phase angle values reflect higher body mass; low values are associated with loss of membrane integrity and permeability, as well as altered cell function [7]. Lower values are associated with malnutrition [8] and with worse prognosis in several conditions, including HIV [9], renal failure [10], and the postoperative state [11].

Because heart failure (and especially ADHF) is associated with major changes in hydration status, BIVA and the phase angle might be useful methods for the assessment of both nutritional and hydration status. In patients with chronic heart failure, BIVA assessment has been shown to be able to detect cachexia and its prognostic consequences [12]; furthermore, low phase angle values were found to be predictors of all-cause mortality [13]. In ADHF, the use of BIVA associated with brain natriuretic peptide (BNP) measurement has been evaluated as a means of guiding fluid management [14]. However, there are no data evaluating whether BIVA parameters are able to detect dynamic changes during episodes of ADHF and after clinical stability.

Therefore, the present study evaluated variations in BIVA parameters and phase angle during hospitalization for ADHF at three distinct time points: on admission, at discharge (after acute recompensation), and in clinical stability (3 mo after discharge).

Materials and methods

Subjects

Patients with heart failure were recruited from the emergency department of a tertiary-care university hospital in Porto Alegre, Brazil. Eligible patients who agreed to participate were enrolled consecutively between May 2011 and June 2012. Eligibility criteria were age >18 y, left ventricular ejection fraction (LVEF) $\leq$ 45%, and hospitalization for ADHF (defined as new-onset decompensated heart failure or decompensation of chronic, established heart failure with symptoms sufficient to warrant hospitalization). Patients were included only if they had a BOSTON score of at least 8 points [15]. The BOSTON score is divided among 3 categories and assigns a maximum of 4 points in each category in a total of 12 points. It includes clinical history, physical exam, thoracic x ray, and they are useful for diagnosing advanced heart failure. The exclusion criteria were: Active malignancy, severe renal failure (serum creatinine level > 2.5 mg/dL or dialysis), presence of pacemaker or implantable cardioverter-defibrillator (because of technical limitations for use of bioelectrical impedance devices), and inability to understand assessment questionnaires.

Patients were followed up and evaluations were performed at three points in time: 1) within the first 36 h of admission (admission); 2) on the day of hospital discharge (discharge); and 3) after 3 mo if the patients were stable, with no clinical signs of decompensation and no hospital admissions in the preceding month (stability).

This study was conducted according to the guidelines of the Declaration of Helsinki, and all procedures involving human patients were approved by the Institutional Research Ethics Committee. Written informed consent was obtained from all patients.

Laboratory and clinical assessment

Data on demographic characteristics, heart failure etiology, echocardiography, and laboratory findings were collected. Functional class was evaluated by the criteria of New York Heart Association Functional Classification [16], where patients are classified from I to IV according to the presentation of symptoms only during physical activity like climbing stairs or walking (classification I to III), or in severe cases, when patients present symptoms at rest (classification IV). Also, the hemodynamic profile was evaluated using the Stevenson's classification [17], which separates patients in quadrants combining physical examination about congestion and perfusion factors, constituting a prognostic marker.

Blood samples were collected for BNP measurement by chemiluminescence (Centaur XP, Siemens, Erlangen, Germany). A visual analog scale was used to assess the grade of dyspnea; values ranged from 0 (no dyspnea) to 10 (severe and persistent dyspnea). All assessments were repeated just before discharge and after 3 mo.

Body composition assessment

Anthropometric variables

Weight was measured at the time of enrollment, in the emergency room, with patients wearing as little clothing as possible, standing upright on the center of an electronic scale (Filizola, São Paulo, Brazil). Weight measurement at discharge and after 3 mo was repeated in the same conditions and time of day.

Bioelectrical impedance analysis

Whole-body bioelectrical impedance was measured using a Biodynamics 450 tetrapolar system (Biodynamics Corp., Seattle, Washington, USA). All measurements were obtained with patients fasting for at least 4 h, using a standard montage of outer and inner electrodes on the right hand and foot. The bioelectrical parameters resistance, reactance, and phase angle were determined using an electric alternating current flow of 800 μA and a frequency of 50 kHz. Resistance and reactance were standardized for height to control for different conductor length (resistance/height and reactance/height). BIVA was performed with a specific software suite using the Italian reference population of Picolli et al. [18], because no data are available for Brazilians and this population was closest to the characteristics of our sample. Phase angle was obtained from the relationship between resistance and reactance, measured by the same equipment, using the following equation: Phase angle (degrees) = arctan (reactance/resistance) $\times$ (180/π).

All measurements, questionnaires and equipment were the same in the three moments of the study, and evaluated by the same investigator.

Statistical analysis

Continuous variables are expressed as mean $\pm$ standard deviation (SD) or median and interquartile range (IQR), and categorical variables as absolute and relative frequencies. Generalized estimating equations were used to assess the variation between continuous variables at the three time points of evaluation (admission, discharge, and stability). The chi-square test was used to evaluate the association of patients with each tolerance ellipsis and the three time points of assessment. Spearman correlations were done among bioelectrical impedance parameters and body weight variations.

In order to further explore the role of BIVA plots, we did classify patients according to hydration status as follows: above the 75% tolerance ellipse (representing a significant increase in hydration according Piccoli et al., under the 75% ellipse (representing normal hydration), and those located in the upper half of the graphic, as representatives of patients migrating to a dehydrated state. Also, patients were classified with "significant congestion" if they were out of 75% ellipsis in BIVA and with "non-significant congestion" if they were on the superior half or between 50% and 75% ellipsis in BIVA.

A *P* value <0.05 was considered statically significant. Analyses were carried out using PASW Statistics 18.0 (SPSS Inc., Chicago, IL, USA) and BIVA software (University of Padova, Padova, Italy) [19].

Results

Demographic and clinical profile of ADHF patients

During enrollment, 242 patients were screened, and 185 were excluded. Main reasons for exclusion were: LVEF higher than 45% or unknown (in 53% of cases), presence of implantable devices (10%), and significant renal failure or hemodialysis (9%).

Fifty-seven patients with heart failure were included in the present study. Demographic and clinical parameters are shown in Table 1. The most prevalent etiology of heart failure was ischemic heart disease (48%), and mean LVEF was 25 $\pm$ 8%. Most patients were on New York Heart Association functional class IV (67%) and hemodynamic profile B. All patients received intravenous furosemide (mean dose 90 $\pm$ 41 mg) within the first 24 h, and most patients were on angiotensin-converting enzyme inhibitors or angiotensin receptor blockers (65%), beta-blockers (53%), and digoxin (68%). At admission, the mean grade of dyspnea was 8 $\pm$ 2 points, regarded as "severe".

Because of the high prevalence of diabetes in this population, a comparative analysis between patients with or without this comorbity was done, and they had no significant differences in