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Accuracy of bioimpedance vector analysis and brain natriuretic peptide in detection of peripheral edema in acute and chronic heart failure

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ABSTRACT

Objective: To evaluate the role of bioelectrical impedance vector analysis (BIVA) and brain natriuretic peptide (BNP) in detecting peripheral congestion in heart failure (HF).
Background: BIVA/BNP are biomarkers for congestion in acute (ADHF) and chronic HF.
Methods: 487 ADHF and 413 chronic HF patients underwent BIVA and BNP tests.
Results: BIVA was more accurate than BNP in detecting peripheral congestion both in ADHF (AUC 0.88 vs 0.57 respectively; $p < 0.001$) and chronic HF patients (AUC 0.89 vs 0.68, respectively; $p < 0.001$). In ADHF patients, the optimal BNP cut-off for discriminating presence or absence of edema was >870 pg/mL (PPV = 48% and NPV = 58%) whereas in chronic HF it was >216 pg/mL (PPV = 18% and NPV = 95%). The BIVA detected edema when the vector fell into the lower pole of 75th percentile tolerance ellipse (PPV = 84% and NPV = 78%) in ADHF, the lower pole of 50% (PPV = 68% and NPV = 95%) in chronic HF.
Conclusions: In HF patients, BIVA is an easy, fast technique to assess peripheral congestion, and is even more accurate than BNP.

Introduction

Clinical congestion plays a key role in the diagnosis, prognosis and guide of therapies in patients affected by heart failure (HF).[1] Most patients with acute decompensated HF (ADHF) present with fluid overload. In chronic HF, i.e. when a stable chronic condition has been reached, the congestion can persist, leading to rehospitalization and death.[2–4]

Of the signs and symptoms associated with fluid accumulation, lower limb edema is the most accurate clinical parameter for a reproducible assessment of peripheral congestion as it occurs in about 60% of patients with ADHF and in 20% with chronic HF.[3–7]

Hemodynamic congestion also increases brain natriuretic peptide (BNP) serum levels[8–10] which can decrease when excess fluid is removed.[11,12] BNP is considered a biomarker of congestion and is

Abbreviations: ADHF, acute decompensated heart failure; AUC, area under the curve; BIA, bioelectrical impedance analysis; BIVA, bioelectrical vector analysis; BNP, brain natriuretic peptide; CHF, chronic heart failure; eCrCl, creatinine clearance; H, height; HF, heart failure; IQR, interquartile range; LR, likelihood ratio; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; NPV, negative predictive value; PPV, positive predictive value; R, resistance; SD, standard deviation; Xc, reactance.

The authors accept responsibility for all aspects of data reliability and freedom from bias and their discussed interpretation.

Conflict of interest: None declared.

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included in a combination of available measurements of clinical congestion that quantify fluid overload.[13] However, in a recent study, BNP did not seem to correlate with the presence or extent of lower extremity edema in ADHF, suggesting that it is not an appropriate biomarker for peripheral congestion.[14]

Recently, whole-body bioelectrical impedance analysis (BIA) has been proposed as a new technique for fluid status detection in HF,[15] on the basis of the theory that fluid accumulation improves the conductivity of an electrical current passing through the body. It was demonstrated that BIA correlates with BNP and hemodynamic congestion,[16–19] and contributes to the diagnosis and prognosis[18,20–23] and decision-making process for tailoring ADHF therapies.[24–27]

In particular, bioelectrical impedance vector analysis (BIVA) provides a quick, immediate and easy semi-quantitative evaluation of fluid status without using specific equations and models required for conventional BIA. As already described by Piccoli et al in 1994,[28] the conductivity of an electrical current passing through the body is described by two fundamental parameters: resistance (R, in Ohm) and reactance (Xc, in Ohm). These parameters are normalized by the subject's height (H) and then plotted in a nomogram as a bivariate vector (see also Fig. 1A). The final bivariate vector is included into one of three probability tolerance ellipses which, respectively, represent the 50th, 75th and 95th percentile of a normal distribution of bivariate vectors resulting from the analysis of a healthy reference population, normalized for gender. The final evaluation of the bivariate vector can be read at two different levels, taking into account the displacement of the vector from the major axis: 1) the displacement above or below the major axis will indicate, respectively, the dehydration or hyperhydration of the patient 2) the displacement toward the left or right side of the longitudinal major axis will give information on an increased or decreased cell mass, respectively.[15]

Therefore, vectors projecting into the lower poles are associated with increased tissue fluid volume (i.e. BIVA wet); conversely, those projecting into the 50th percentile or the upper poles of the ellipses indicate normal or decreased tissue fluid volume, respectively (i.e. BIVA dry) (Fig. 1A). The lower pole of the 75th percentile tolerance ellipse is the threshold for clinical edema, as outlined in studies involving patients suffering from kidney failure.[27–29] More recently, in ADHF patients, pitting edema was detected when a single vector was close to the lower pole of the 95th percentile tolerance ellipse.[20]

Although the above mentioned evidence suggests that BIVA and BNP can be useful and promising biomarkers for congestion,[30] their clinical usefulness in detecting peripheral congestion in HF has not been fully explored. Therefore, the objective of this study was to assess and compare their accuracy in detecting peripheral congestion in a large population of ADHF and chronic HF patients.

Material and methods

This is a retrospective study. We reviewed the clinical data of patients who had been admitted to the Cardiology Unit of Altamura Hospital – Bari (Italy) due to ADHF[1] and/or to the heart failure outpatients unit during chronic HF[1] routine follow-up between January 2009 and November 2013. Nine hundred patients were consecutively enrolled: 487 had been admitted for ADFH and 413 for chronic HF.

All medical records were reviewed by two of the authors (FM and MI). At the time of admission, the baseline characteristics, underlying disease, comorbidities, physical examination, functional clinical status evaluated by means of the New York Heart Association (NYHA) classification, blood chemistry data, left ventricular ejection fraction (LVEF), BIVA and drugs administered at hospital admission were considered. Preserved left ventricular ejection fraction was defined as LVEF >45%, evaluated by Simpon's biplane method.[31] The Cockroft-Gault equation was used to estimate creatinine clearance: eCrCl (mL/min) = [(140 – age) × (weight)]/(72 x serum creatinine) x 0.85 (if female).[32] All of these measurements were performed as a routine evaluation of the patients admitted to our department both in ward and ambulatory settings.

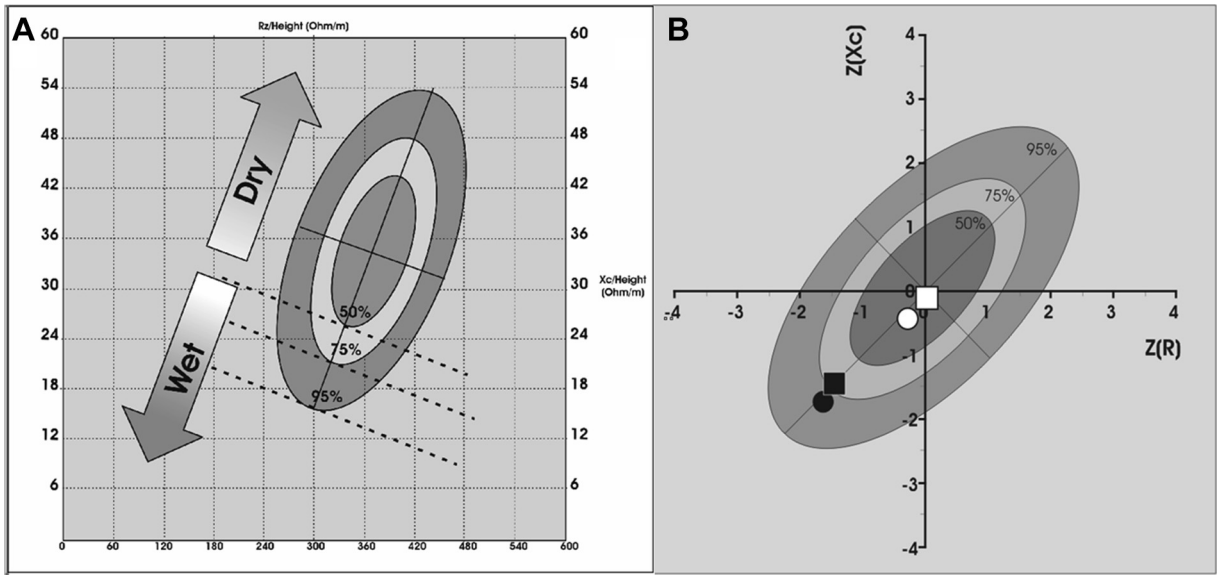

Fig. 1. A) The RXc graph shows three tolerance ellipses, plotting resistance (R) and reactance (Xc) standardized by height (H), and include 50th, 75th and 95th percentiles of healthy individual points, respectively. Vector displacements parallel to the major axis of tolerance ellipses indicate different soft tissue hydration. Vectors that project into lower poles are associated with increased hydration (BIVA wet), and conversely vectors that terminate in the upper and the lower pole of 50% of tolerance ellipse indicate normal or decreased hydration (BIVA dry). B) Mean impedance vectors with their SD plotted on the 3 tolerance ellipses (50th, 75th, 95th percentiles): ●) mean vector of ADHF patients with pitting edema; ○) mean vector of ADHF patients without pitting edema; ■) mean vector of CHF patients with pitting edema; and □) mean vector of CHF patients without pitting edema.