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Original Contribution

Bioelectrical impedance analysis for heart failure diagnosis in the ED

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ABSTRACT

Introduction: The aim of this study was to evaluate bioimpedance vector analysis (BIVA) for the diagnosis of acute heart failure (AHF) in patients presenting with acute dyspnea to the emergency department (ED).
Methods: Patients with acute dyspnea presenting to the ED were prospectively enrolled. Four parameters were assessed: resistance (R), reactance (Ra), total body water (TBW), and extracellular body water (EBW). Brain natriuretic peptide (BNP) measures and cardiac ultrasound studies were performed in all patients at admission. Patients were classified into AHF and non-AHF groups retrospectively by expert cardiologists.
Results: Seventy-seven patients (39 men; age, 68 ± 14 years; weight, 79.8 ± 20.6 kg) were included. Of the 4 BIVA parameters, Ra was significantly lower in the AHF compared to non-AHF group (32.7 ± 14.3 vs 45.4 ± 19.7; $P < .001$). Brain natriuretic peptide levels were significantly higher in the AHF group (1050.3 ± 989 vs 148.7 ± 181.1 ng/L; $P < .001$). Reactance levels were significantly correlated to BNP levels ($r = -0.5$; $P < .001$). Patients with different mitral valve Doppler profiles (E/e' ≤ 8, E/e' ≥9 and <15, and E/e' ≥ 15) had significant differences in Ra values (47.9 ± 19.9, 34.7 ± 19.4, and 31.2 ± 11.7, respectively; $P = .003$). Overall, the sensitivity of BIVA for AHF diagnosis with a Ra cutoff at 39 Ω was 67% with a specificity of 76% and an area under the curve at 0.76. However, Ra did not significantly improve the area under the curve of BNP for the diagnosis of AHF (P = not significant).
Conclusion: In a population of patients presenting to the ED with dyspnea, BIVA was significantly related to the AHF status but did not improve the diagnostic performance for AHF in addition to BNP alone.

1. Introduction

Dyspnea is a common symptom for emergency department (ED) consultation. It is also the most common symptom at presentation for acute heart failure (AHF) [1–3]. However, this symptom is not specific and is present in many other non–cardiac-related diseases. Acute heart failure represents the most common cause of hospitalization through the Medicare system in the United States. Most of these hospitalizations are secondary to chronic heart failure (CHF) decompensation [3,4].

Several reports show that an accurate diagnosis with early and appropriate therapeutic management improves the prognosis of patients with AHF [5,6]. Fonseca [7] showed that only 25% to 60% of AHFs were correctly diagnosed in the ED. In addition, symptoms and clinical presentation for this pathology have limited sensitivity and specificity [1,3]. There is a need for additional tests to improve diagnostic capacity and enhance timely therapeutic management.

Brain natriuretic peptide (BNP) testing has emerged as an efficient diagnostic tool for AHF detection [8,9]. However, its diagnostic performance can be limited in selected subgroups of AHF patients. Patients with CHF may paradoxically have high or low values of BNP [8–10]. Similarly, BNP in "gray zone" values also raise problems of interpretation. Other noninvasive HF diagnostic tools such as chest radiography or cardiac ultrasound study also have limitations in terms of either diagnostic performance or ED availability [2,11,12].

One of the proposed methods for the diagnosis of AHF and evaluation of body fluid overload is electrical bioimpedance [13]. It is quick, reproducible, noninvasive, and inexpensive. The impedance of a patient characterizes the opposition that body tissues present to an electric current's transmission. Bioimpedance has been studied in various fields such as nutrition [14], nephrology [15], hepatology [16], and cardiology [17–19].

Preliminary clinical studies in selected groups of patients have shown a significant relationship between impedance parameters and AHF [20–24]. The fluid overload present in AHF leads to a decrease in

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body impedance. Measurement of patient's bioimpedance in the ED could therefore be relevant in the AHF diagnostic workup.

The principal aim of our study was to evaluate the diagnostic performance of bioelectrical impedance vector analysis in patients admitted to the ED for dyspnea and compare it to BNP and echocardiographic parameters for the accurate diagnosis of AHF.

2. Material and methods

2.1. Study population

This study was a prospective monocentric observational study. The study was conducted from February to June 2013 at the Emergency Cardiology Consultation (ECC) at the University Hospital of L. Pradel at Bron (France), a tertiary referral center. Our institution is specialized in cardiac and pulmonary diseases, and the attached ED is specialized in cardiac and pulmonary emergencies and symptoms. Patients who consult in this ECC are referred by themselves, their general practitioner, or the mobile intensive care units (911 services in France). All consecutive patients presenting to the ECC with symptoms of dyspnea were eligible for inclusion.

Exclusion criteria were as follows: acute coronary syndrome, age younger than 18 years, refusal to participate in the study, and pregnancy.

Patients who satisfied the inclusion criteria were informed of the study protocol. Free and informed consent was obtained from each patient included in this study. The study protocol was approved by our Institutional Review Board.

2.2. Diagnostic workup

For each patient, dyspnea was assessed according to the New York Heart Association classification. Previous medical history and baseline clinical and biological characteristics were reported. Chest radiography was performed at the discretion of the attending physician at the time of admission in the ECC.

Serum BNP levels (immunoassay method; Architect I2000) were assessed upon admission. The upper threshold of normal value used for the diagnosis of AHF according to our local laboratory was greater than or equal to 100 ng/L [9].

A transthoracic cardiac ultrasound scan (GE Vivid S5; General Electric, Milwaukee, WI) was performed in all patients. Left ventricular ejection fraction was measured, and left ventricular end-diastolic pressure (LVEDP) was assessed according to the E/e' ratio obtained by Doppler tissue imaging at the mitral annulus in the lateral wall. The LVEDP classification was based on the American Society of Cardiology ultrasound guidelines [25]. An E/e ' ratio less than or equal to 8 was classified as normal LVEDP (class I), a ratio between 9 and 14 was classified as intermediate LVEDP (class II), and a ratio greater than or equal to 15 was considered as elevated LVEDP (class III). If LVEDP was not possible to assess (atrial fibrillation, mitral valve disorder, severe segmental wall motion), patients were arbitrarily included into the class II category.

The bioimpedance measurements were performed with a Z-Metrix BioparhΩm device (Z-Metrix, BioparhΩm, Bourget-du-Lac, France) at patient's admission. Four electrodes were placed on the patient's body: 2 on the right hand (between the metacarpals) and 2 on the side of the right calf (1 above the lateral malleolus and 1 below). Electrodes were placed apart by a space of approximately 4.0 cm. The measurement was performed on arrival at the ED, before initiation of any therapy, and was completed in supine position. Each analysis took 15 seconds, and results obtained were recorded electronically. The different parameters measured were total body water (TBW), extracellular water (EEW), reactance (Ra), and resistance (R).

To assess normal values of bioimpedance measures, we also performed bioimpedance measurements (TBW, ECW, Ra, and R) of 14 healthy volunteers.

The impedance is the sum of R and Ra. These values are derived from the impedance Ohm law stating that when an electrical current passes through the human body, the voltage's difference between 2 points is proportional to the impedance of this body [13].

One month after admission to the ED, all patients' medical records, therapeutic management, and laboratory results (all biology, BNP, cardiac ultrasound, chest radiograph, and any other examination performed during stay in ECC or in subsequent hospitalization) were reviewed by 2 independent cardiology experts blinded to bioimpedance measurements.

Clinical and laboratory data in medical records were reviewed to establish the etiologic diagnosis of dyspnea. Patients were then classified into the AHF or non-AHF group. This expert classification set the reference for our study population.

2.3. Statistical analysis

Qualitative variables are expressed as percentages or absolute numerical value, whereas continuous variables are expressed as mean ± standard deviation or median and interquartile range for non-Gaussian distribution. Resistance and Ra are expressed in ohms (Ω); total and extracellular water, in liters; and BNP, in nanograms per liter.

The comparison between groups was performed by a nonparametric Wilcoxon rank sum test for quantitative variables and a χ^2 or Fisher test for qualitative variables. The various data measured by bioimpedance were related to final discharge diagnosis of heart failure by univariate logistic regression. We performed multivariate logistic regression models to assess the effect of prespecified potential confounders such as age or renal failure. The first model integrated each bioimpedance vector analysis (BIVA) parameter separately adjusting for age. The second model integrated each BIVA parameter adjusting for age and glomerular filtration rate (GFR) value at admission. The relationship between BNP levels and each bioimpedance parameter was assessed by linear regression. The relationship between different LVEDP categories and each bioimpedance parameter was assessed by ordinal logistic regression.

In the multivariable analysis, the association between BIVA and heart failure was analyzed using 3 models with different covariate adjustments: model 1 included age, model 2 included age and GFR, and model 3 included model 2 plus BNP levels.

We tested and compared the discrimination ability of BIVA and BNP for heart failure in the univariate and multivariate analyses beyond through differences in area under the curve (AUC) derived from receiver operating characteristic (ROC) analysis. The AUCs were computed based on the predicted risk from multivariate modeling and compared using a parametric method. Comparisons between ROC curves obtained with different models were performed with *C* statistics. Tests were considered significant with a P value < .05. All statistical measurements were performed using SPSS 20.0 (Chicago, IL) software and GraphPad Software Version 6.0 (San Diego, CA).

3. Results

3.1. Study population characteristics

There were 77 patients, with a mean age of 68 ± 14 years. Thirty-eight (49.4%) women were included in the study. The principal patient characteristics at presentation are presented in Table 1 according to heart failure status. The diagnosis of AHF was confirmed for 37 (48%) patients of the study population.

3.2. BIVA measurements

The respective values of Ra, R, TBW, and EEW in the population study are presented in Table 2. Of the 4 parameters assessed by BIVA,