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Longitudinal and Transversal Bioimpedance Measurements in Addition to Diagnosis of Heart Failure

N Ribas[1], L Nescolarde[2], M Domingo[1], P Gastelurrutia[1], A Bayés-Genis[1], J Rosell-Ferrer[2]
[1] Service of Cardiology, Hospital de la Santa Creu I Sant Pau, c/ Sant Antoni Maria Claret, 167, 08025 Barcelona, Spain
[2] Department of Electronic, Technical University of Catalonia, Barcelona, Spain

E-mail: lexa@eel.upc.edu

Abstract. Heart Failure (HF) is a clinical syndrome characterised by signs of systemic and pulmonary fluid retention, shortness of breath and/or fatigue. There is a lack of reliable indicators of disease state. Benefits and applicability of non-invasive bioimpedance measurement in the hydration state of soft tissues have been validated, fundamentally, in dialysis patients. Four impedance configurations (2 longitudinal and 2 transversal) were analyzed in 48 HF patients (M=28, F=20) classified according to a clinical disease severity score (CDSS) derived from the Framingham criteria: CDSS≤2 (G1: M= 23, F= 14) and CDSS>2 (G2: M= 5, F= 6). The aim of this study is to analyze longitudinal and transversal bioimpedance measurement at 50 kHz, in addition to clinical diagnosis parameters of heart failure, including: clinical disease severity score (CDSS) and a biomarker concentrations (NT-proBNP). The Kolmogorov-Smirnov test was used for the normality test of all variables. The CDSS, NTproBNP and impedance parameters between groups (G1 and G2) were compared by mean of Mann Withney U-test. The statistical significance was considered with $P < 0.05$. Whole-body impedance measured was analyzed using RXc graph.

1. Introduction

Heart failure (HF) is a clinical syndrome defined by the inability of the heart to provide adequate blood flow to other organs. Consequently, it generates systemic and pulmonary fluid retention. This congestion is the responsible of the symptoms (breathlessness, fatigue, anorexia) and signs (peripheral oedema, hepatomegaly, rales over lungs) that are used in the diagnosis of the exacerbation of HF. However, their lack of sensitivity and the importance to detect congestion in early stages supports the need of more aggressive management of these patients. For this reason, biomarkers concentration, particularly B-type natriuretic peptide (BNP) and its amino-terminal cleavage equivalent (NT-proBNP) [1] helps to the clinical features in the diagnosis of the syndrome. However, they also have a significant heterogeneity, and better markers are needed. The feasibility of segmental bioimpedance measurement [5] in the determination of segmental volumes and regional fluid shifts to overcome the limitations of whole-body impedance methods is an alternative.

The bioelectrical impedance vector analysis BIVA [2] is a non invasive procedure easily applicable in the clinic due to its sensitivity to detect changes in the hydration of soft tissues. This method is unaffected by regression adjustments to estimate body composition, body geometry or hydration state. The aim of this study is to analyze longitudinal and transversal bioimpedance measurement at 50 kHz, in addition to clinical diagnosis parameters of heart failure.

2. Methods

2.1 Patients

Patient clinical status, NT-proBNP levels and bioimpedance measurements were obtained from 48 patients (M= 28; F= 20). The study was approved by the Local Ethics Committee and informed consent was obtained from each patient. Exclusion criteria included the presence of: 1) pacemaker or implantable automatic defibrillator; 2) large metallic prosthesis such as hip or knee prosthesis; and 3) limb amputations. HF clinical disease severity score (CDSS) based on Framingham criteria was used to diagnose destabilized HF. Two groups of patients were identified based on clinical criteria: group G1 of stable HF patients with CDSS ≤ 2, and group G2 of non-stable congestive HF patients with CDSS > 2. NT-proBNP levels were measured by electrochemiluminescence immunoassay using Elecsys 1010 analyzer (Roche Diagnostics GmbH, Mannheim, Germany).

2.2 Bioimpedance Measurements

Impedance measurements were taken with model SFB7 (ImpediMed, Queensland, Australia) at 50 kHz with injected current of 800 μA. The specific measurement error of the system is lower than 1 Ω and 1 ° at 50 kHz using electrical models. Tetrapolar bioimpedance measurements were made in four electrode configurations: whole-body (RS), longitudinal leg (LLEG), transversal bioimpedance measurement in cross-section of the right hemithorax (TTH), and transversal bioimpedance measurement in cross-section of the hepatic abdominal region (TAB). Disposable pre-gelled Ag/AgCl (3M Red Dot, Canada) electrodes were used.

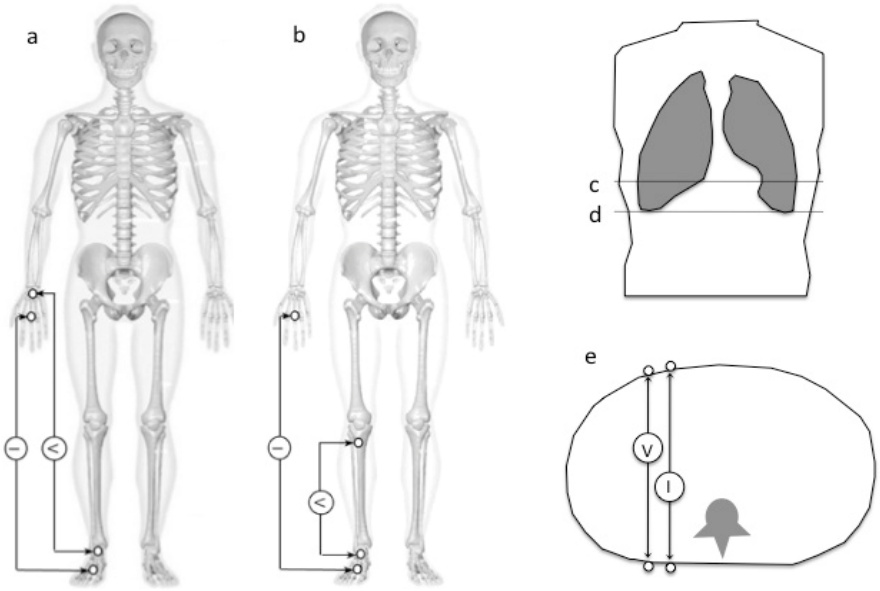

Figure 1. Electrode locations for longitudinal measurements: whole-body (a), longitudinal leg (b). Transversal measurements location: cross-section of the right hemithorax (c), cross-section of the hepatic abdominal region (d). Electrode locations for transversal measurements (e).

2.3 Statistical Methods

Forty-eight HF patients were identified in two groups of patients based on clinical criteria: group G1 of stable HF patients with CDSS ≤ 2, and group G2 of non-stable congestive HF patients with CDSS > 2. All data are expressed as mean values (± SD). Individual bioelectrical impedance vector, in whole-body (RS) was analysed in the RXc-graph [2] with tolerance ellipses (50%, 75% and 95%) of the reference population [3]. Whole-body (RS) impedance measured was normalized by height of the patients (H), longitudinal leg (LLEG) by leg length (LL); transversal bioimpedance measurement in cross-section of the right hemithorax (TTH) by perimeter of the thorax (PT); and finally transversal bioimpedance measurement in cross-section of the hepatic abdominal region (TAB) by abdominal circumference (AC). Kolmogorov-Smirnov test was used for the normality test of clinical, laboratory and bioimpedance vector components. For differences between impedance vector components with clinical and laboratory parameters the Mann-Whitney test was used. Minitab software version 15.1.0 (Minitab, Inc.) was used for statistical analysis. Statistical significance was considered with $p < 0.05$.

3. Results

Table 1 and table 2 show the mean ± standard deviation (SD) of CDSS, NTproBNP, impedance parameters (R and Xc), and Mann Whitney-U test, for male and female sample.

Table 1. Clinical and impedance parameters in male sample

	G1 (CDSS ≤ 2) N=23	G2 (CDSS > 2) N=5	P
CDSS	1.0 ± 0.5	3.3 ± 1.1	0.000**
NTpro BNP	2777 ± 3441	2936 ± 2380	0.589
RS, R/H	304.5 ± 63.0	247.9 ± 50.9	0.081
RS, Xc/H	25.5 ± 5.7	19.6 ± 6.9	0.047*
LLEG, R/LL	398.0 ± 98.0	237.1 ± 48.5	0.004*
LLEG, Xc/LL	30.5 ± 13.8	11.8 ± 3.8	0.005*
TTH, R/PT	42.3 ± 10.4	31.9 ± 14.2	0.093
TTH, Xc/PT	4.7 ± 1.8	4.1 ± 1.6	0.435
TAB, R/AC	44.8 ± 13.2	32.9 ± 13.1	0.150
TAB, Xc/AC	4.6 ± 1.7	3.4 ± 0.5	0.026*

Table 2. Clinical and impedance parameters in female sample

	G1 (CDSS ≤ 2) N=14	G2 (CDSS > 2) N=6	P
CDSS	1.4 ± 0.4	3.1 ± 1.0	0.000**
NTpro BNP	3317 ± 3416	665 ± 167	0.107
RS, R/H	322.2 ± 82.1	320.5 ± 68.8	1.000
RS, Xc/H	25.2 ± 7.0	28.4 ± 7.8	0.713
L-LEG, R/LL	360.9 ± 115.5	396.2 ± 144.5	0.386
L-LEG, Xc/LL	23.0 ± 9.5	30.0 ± 17.6	0.302
T-TH, R/PT	46.6± 12.6	42.2 ± 8.9	0.386
T-TH, Xc/PT	4.8 ± 0.9	5.3 ± 0.9	0.231
T-AB, R/AC	53.0 ± 19.2	50.8 ± 12.9	0.836
T-AB, Xc/AC	4.9 ± 1.0	4.8 ± 2.3	0.483

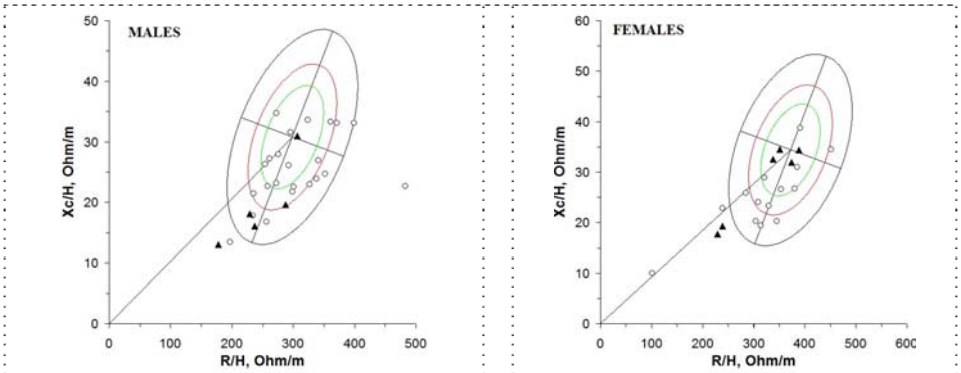

Figure 2. Individual vectors for 48 patients with CDSS≤2 (G1: M= 23, F= 14) and with CDSS>2 (G2: M= 5, F= 6) in the tolerance ellipses for the reference population [3].

4. Discussion and Conclusions

The Mann-Whitney U test results in the male sample (table 1) indicate a statistically significant difference in R and Xc parameters in the L-LEG segment; and Xc parameters in the T-AB and RS segment. In BIVA, R/H provides information of the hydration state and Xc/H the structure of soft tissues. In some previous studies, the inferior pole of the 75% tolerance ellipse was considered the threshold for oedema [4]. Figure 2 shows individual impedance vector in RS configuration. Some patients classified as G1 with CDSS ≤ 2 were located by BIVA in the hyper-hydration region; and some patients classified as G2 with CDSS > 2 were located in the normal-hydration region in males and more prominent in female's sample. This situation and the small sample size might be the reason why the table 2 not shows statistically significant results in any segment. Patterson *et al* 1988 analyzed the feasibility of segmental bioimpedance measurement in the determination of segmental volumes and regional fluid shifts to overcome the limitations of whole-body (RS) impedance methods. This preliminary study suggests that in HF longitudinal bioimpedance measurement in leg segment (L-LEG) provides additional information to clinical examination and could even reflect sub-clinical hyper-hydration.

Acknowledgments

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