Clinical Nutrition 33 (2014) 673–677

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

Combined evaluation of nutrition and hydration in dialysis patients with bioelectrical impedance vector analysis (BIVA)

Antonio Piccoli*, Marta Codognotto, Paola Piasentin, Agostino Naso

Department of Medicine DIMED, University of Padova, Policlinico IV Piano, via Giustiniani 2, I-35128 Padova, Italy

ARTICLE INFO

Article history:
Received 14 December 2012
Accepted 19 August 2013

Keywords:
BIVA
Body hydration
Hemodialysis
Malnutrition
Subjective global assessment
Ultrafiltration

SUMMARY

Background & aims: Body hydration changes continuously in hemodialysis patients. The Subjective Global Assessment (SGA) is used for the nutritional evaluation but it does not allow a direct evaluation of hydration. Bioelectrical impedance vector analysis (BIVA) is very sensitive to hydration. The potential of the combined evaluation of hydration and nutrition with SGA and BIVA is still lacking.

Methods: Observational cross-sectional study on 130 (94 Male) uremic patients undergoing chronic hemodialysis three times a week. Nutritional status was evaluated with the SGA. Each subject was classified as SGA-A (normal nutritional status), SGA-B (moderate malnutrition), or SGA-C (severe malnutrition). Body hydration was evaluated with BIVA. The two vector components resistance (R) and reactance (Xc) were normalized by the subject's height and standardized as bivariate Z-score, i.e. $Z(R)$ and Z(Xc).

Results: Undernutrition influenced impedance vector distribution both before and after a dialysis session. In pre-dialysis, the mean vector of SGA A was inside the 50% tolerance ellipse. In SGA B and C, $Z(R)$ was increased and Z(Xc) decreased, indicating a progressive loss of soft tissue mass. Fluid removal with dialysis increased both $Z(R)$ and Z(Xc) in SGA A and B but not in C. With ROC curve analysis on the slope of increase, we found the cutoff value of 27.8° below which undernutrition was present, either moderate or severe. The area under the ROC curve was 77.7° (95% CI 69.5–84.5, $P < .0001$) with sensitivity 75.9%, specificity 78.6%, positive predicted value 74.6%, and negative predicted value 79%.

Conclusions: The distribution of impedance vectors is associated with the SGA classification of patients. The change in body hydration in each SGA category can be detected with BIVA.

1. Introduction

Protein-energy wasting is highly prevalent in uremic patients maintained on chronic dialysis and is associated with increased mortality.[1] The Subjective Global Assessment (SGA) of nutritional status is used to assess the nutritional status of chronic dialysis patients. It is a tool that uses four components of a medical history (weight loss, changes in dietary intake, gastrointestinal symptoms, functional capacity) and four components of a brief physical examination (muscle, subcutaneous fat, sacral and ankle edema, ascites) to assess nutritional status classified as a well nourished (SGA A), moderately malnourished (SGA B), or severely malnourished (SGA C).[2] Since 2000 the National Kidney Foundation Kidney Disease/Dialysis Outcomes and Quality Initiative (K/DOQI) has recommended the use of the SGA for assessing the nutritional status of dialysis patients.[3]

SGA does not assess directly the body hydration. In dialysis patients, the evaluation of nutritional status may be biased because of the frequent changes in the body hydration. Indeed, at physical examination, a same soft tissue mass can be increased or decreased by a different hydration level. In previous works we demonstrated that bioelectrical impedance vector analysis (BIVA) has the potential for the combined evaluation of hydration and nutrition.[4–9]

BIVA is based on patterns of the resistance-reactance graph (RXc graph) relating body impedance to body hydration without equations (Fig. 1).[4–11] Changes in tissue hydration status below 500 mL are detected and ranked. Impedance is represented with a point in the R–Xc plane which is a combination of resistance, R, i.e. the opposition to the flow of an injected alternating current, at any current frequency, through intra- and extracellular ionic solutions, and reactance, Xc, i.e. the dielectric or capacitative component of cell membranes and organelles, and tissue interfaces. Clinical information on hydration is obtained through patterns of vector distribution with respect to the healthy population of the same race, sex, class of body mass index (i.e. the body weight in Kg divided by the squared height in meter (BMI)), and class of age.

* Corresponding author. Tel.: +39 3358256780; fax: +39 0498212151.
E-mail address: apiccoli@unipd.it (A. Piccoli).

0261-5614/$ – see front matter © 2013 Elsevier Ltd and European Society for Clinical Nutrition and Metabolism. All rights reserved.
http://dx.doi.org/10.1016/j.clnu.2013.08.007

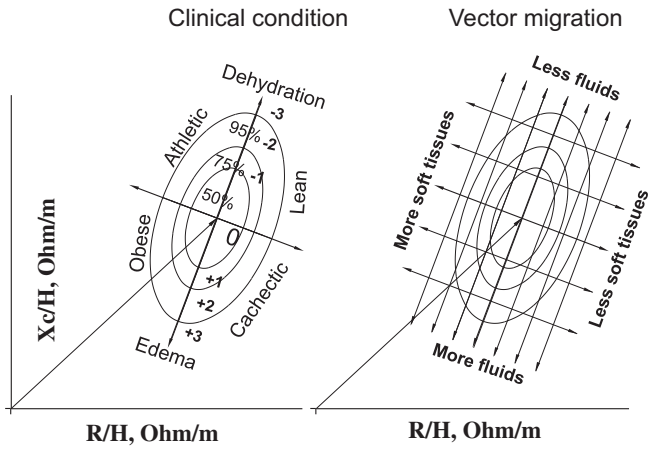

Fig. 1. Patterns of impedance vector migration. With BIVA method, the intersubject variability of the impedance vector is represented with the bivariate normal distribution, i.e. a graph with elliptical probability regions (50, 75, and 95% tolerance ellipses) on the R–Xc plane normalized by the height (R/H, and Xc/H, in Ohm/m). Vector position on the RXc graph is interpreted and ranked following two directions: (1) Vector displacements parallel to the major axis of tolerance ellipses indicate progressive changes in soft tissue hydration; and (2) vectors lying on the left side, above the major axis, or on the right side, below the major axis of tolerance ellipses indicate more or less soft tissues, respectively. *R*: Resistance; Xc: reactance; *H*: height.

Vector position on the RXc graph is interpreted following two directions on the R–Xc plane, as depicted in Fig. 1: (1) Vector displacements parallel to the major axis of tolerance ellipses indicate progressive changes in tissue hydration (dehydration with long vectors, out of the upper poles of the 75 and 95%, and hyperhydration with apparent edema, with short vectors, out of the lower poles of 75 and 95%); (2) Peripheral vectors lying on the left side of the major axis, or on the right side of the major axis of tolerance ellipses indicate more or less cell mass, respectively (i.e. vectors with a comparable *R* value and a higher or lower Xc value, respectively).

In this study we evaluated the distribution of impedance vectors according to SGA classification and secondly, the behavior of impedance vectors during fluid removal with hemodialysis in the different SGA classes.

2. Materials and methods

2.1. Experimental design

This was an observational cross-sectional study of uremic patients undergoing chronic hemodialysis three times a week at the University Hospital of Padua, Italy. Patients were eligible for inclusion if they were Caucasian adults of any age and BMI. One hundred and eighty patients were screened. Fifty patients out of 180 were excluded: 31 with non-compliance, unconsciousness or dementia, 10 with an amputation, and 9 with diffuse skin lesions or edema secondary to vein disorders. One hundred and thirty patients participated in the study.

The study was approved by the local ethics committee in agreement with Helsinki statements. After obtaining informed consent, before the hemodialysis session, clinical and epidemiological data (dialytic age, causes of uremia, diabetes, heart diseases, obliterating lower limbs arteriopathies) were recorded and the SGA was determined by one operator (PP). Each subject was classified as SGA A (normal nutritional status), SGA B (moderate malnutrition), or SGA C (severe malnutrition).

Blood samples were taken for the routine laboratory determinations (albumin, hemoglobin, C-reactive protein (CRP), leucocytes and lymphocytes count). The total ultrafiltration was calculated as a difference between initial and final body weight and expressed in mL. The body weight was measured with the bed-scale where the subject lay, with an accuracy of 0.1 Kg.

2.2. Statistical methods

All continuous variables followed the normal distribution (Kolmogorov–Smirnov test for normality, and parametric tests of significance) with the exception of CRP which was transformed into log-normal distribution (results expressed as geometric mean).

One-way analysis of variance (ANOVA) with multiple comparisons of means according to Bonferroni criterion (when significant *F* test), Student's *t* test for paired data, simple correlation coefficient (*r*), and X^2 test for frequencies were calculated with SPSS (ver. 18, Chicago, IL). The receiver operating characteristic (ROC) curve analysis was performed with the MedCalc software (vers. 11.5,

Table 1
Characteristics of patients are reported for the three SGA classes. Noteworthy, dialysis duration did not differ by SGA classes as did comorbidities and causes of uremia. Continuous variables are reported as mean (SD) and are tested with ANOVA (*F* test). Frequencies of events are percentages and are tested with the X^2 test.

	SGA-A, $n = 70$, 54%	SGA-B, $n = 37$, 28%	SGA-C, $n = 23$, 18%	*P*(*F*)	Significant comparisons
Age, years	65.8 (14.2)	74.4 (10.1)	74.3 (10)	.001	A < B,C
Dialysis duration, month	42.8 (43.1)	35.0 (31.9)	42.5 (44.6)	ns	
Albumin, g/L	38.1 (3.4)	36.2 (4.4)	32.2 (3.9)	<.001	A > B > C
Hb, g/L	113.1 (13.0)	112.2 (16.4)	100.0 (17.7)	.003	A,B > C
LogCRP, mg/L	5.1 (2.0)	8.8 (2.1)	14.3 (2.7)	<.001	A < B,C
WBC/mcL	6476 (2032)	6779 (1995)	7747 (2606)	ns	
Lymphocytes/mcL	1315 (407)	1454 (549)	1066 (444)	.007	A,B > C
BMI, Kg/m^2	25.3 (3.6)	24.2 (3.7)	20.7 (3.1)	<.001	A,B > C
Comorbidities				*P*(X^2)	
Diabetes, %	22.8	32.4	21.7	ns	
Heart diseases, %	57.1	64.9	78.3	ns	
Lower limbs arteriopathy %	14.3	29.7	26.0	ns	
Causes of uremia					
Diabetes, %	12.9	16.2	13.0	ns	
Nephroangiosclerosis, %	15.7	18.9	17.4	ns	
Policystic KD, %	11.4	10.8	0.0	ns	
Glomerulonephritis, %	14.3	16.2	8.7	ns	
Unknown, %	37.1	35.1	39.1	ns	

LogCRP: logarithm (C-reactive protein); WBC: White bood cells; A < B,C: the mean in SGA A < the means in SGA B and SGA C; A > B > C: the mean in SGA A > the mean in SGA B > the mean in SGA C; A,B > C: the means in SGA A and in SGA B > the mean in SGA C; KD: Kidney Disease; ns: not significant.