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A new marker for nutritional assessment in acute care geriatric units: The phase angle measured by bioelectrical impedance analysis

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1. Introduction

Protein-energy undernutrition is a pathology in the heart of the comprehensive care of elderly people. It contributes to the occurrence of many complications such as nosocomial infections (Paillaud et al., 2005), bed sores (Reed et al., 2003), falls (Lumbers et al., 2001), or the start of dependence (Janssen, 2006) and leads to increases in mortality (Herrmann et al., 1992), lengths of hospital stays (Agarwal et al., 2013), and adverse events for all chronic pathologies (Herrmann et al., 1992). A link also exists between the evolution of the nutritional status of elderly people and the appearance of frailty, predictive of a decrease in functional capacity (Bonnefoy et al., 2014).

It therefore seems vital to be able to correctly assess the nutritional status of elderly people during the care of their aging. The diagnostic criteria used in France were provided by the French National Health Authority (the Haute Autorité de Santé - HAS) in 2007 and include the Body Mass Index (BMI), the percentage of weight loss, serum albumin, and the Mini Nutritional Assessment (MNA) (Haute Autorité de Santé, n.d.). However, the HAS acknowledges that certain limits exist for their use with respect to neurocognitive disorders, inflammatory situations and imbalances in the distribution of the body fluids (fluid retention or fluid inflation) (Haute Autorité de Santé, n.d.). Furthermore, these criteria doesn't make it possible to assess the muscular mass or the physical performance, whereas the aging is conventionally associated with a decline in lean body mass and an increase in visceral fat mass (Landi et al., 2014). At these changes can be added a fat infiltration into muscle for highests BMIs, conducting to sarcopenic obesity, and where HAS criteria are again limited (Cruz-Jentoft et al., 2010).

In acute care geriatric units, the incidence of undernutrition is estimated to be between 30 and 70%, with the patients frequently suffering from neurocognitive disorders, inflammatory situations, and imbalances in fluid body distribution (Haute Autorité de Santé, n.d.). The essential nutritional evaluation is therefore particularly difficult, which led us to consider new tools.

The Bioelectrical Impedance Analysis (BIA) is a technique that is reproducible, non-invasive, adapted to nutritional evaluation and easy to use (Kyle et al., 2004). It allows the raw electrical parameters of the human body to be measured: the resistance (R) and the reactance (Xc), as well as the calculation of the fat mass and the fat-free mass using regression equations. A recent review of the literature put in question the pertinence of the BIA for measuring body compartments but highlighted the interest of other mathematical models such as the 50 kHz phase angle (50PA), which is calculated from raw electrical data using the formula: "Phase angle = arctangent $(Xc/R) * 180^\circ / \pi$". The 50PA appears promising for the analysis of the nutritional status (Norman et al., 2012). The phase angle value in elderly subjects over 70 years old was evaluated on average $6.19^\circ \pm 0.97$ for men and $5.64^\circ \pm 1.02$ for women (Barbosa-Silva et al., 2005). Its value is influenced by age and fat free mass which makes it an interesting marker in sarcopenia (Gonzalez et al., 2016). It may reflect the loss of muscle mass in healthy elderly subjects, especially in men (Saragat et al., 2014). It's decrease may be the result of a nutritional change or an inflammatory situation, making it a prognostic marker in a number of situations (Norman et al., 2012; Stobäus et al., 2011; Kyle et al., 2013). Whereas the link between

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the nutritional status and a decrease in the phase angle is now well documented, very few studies have considered its practical use in nutritional assessment. Consequently, we were particularly interested in the use of phase angle as a diagnostic marker for undernutrition in patients hospitalized in the acute care geriatric unit.

The main objective was therefore to assess the diagnosis value of the phase angle, measured at admission, in the diagnosis of undernutrition, as carried out in clinical practice using the National Health Authority's criteria. Secondarily, we wished to identify the different factors likely to distort the diagnosis value of the phase angle.

2. Materials and methods

2.1. Description of the study and the patients

It is a monocentric and prospective study performed in 3 acute care geriatric units of the teaching hospital (CHU) in Clermont Ferrand, based in the hospital in Riom. All data used were taken as part of routine care and in accordance with the normal practices of the department. All patients admitted to the acute care geriatric unit between June and August 2014 were considered for possible inclusion. To be included, the patients had to be aged over 70 and had to have undergone a nutritional assessment within the first 72 h of hospitalization. This assessment consisted of the determination of the albumin level, a weight measurement, a search for a previous weight when available, a calculation of the BMI, as well as a bioelectrical impedance analysis. Patients were excluded if there was no performed BIA due to skin lesions at the sites where the electrodes are placed, or if an amputation limb or if the patient had a pacemaker or a cardiac defibrillator. Rehospitalized patients who had already been included were not reincluded. Study ethics approval was obtained on October 2016 (CECIC Rhône-Alpes-Auvergne, Grenoble, IRB 5921).

2.2. General characteristics

The population is described according to the age and gender of the patients, the nutritional assessment markers, BIA data, and by different co-morbidities taken from the medical files, such as the presence of diabetes, Parkinson's disease, cognitive disorders, chronic inflammatory disease, malignant neoplasms, or a chronic organ dysfunction: heart failure, respiratory failure, liver failure, kidney failure (Cockcroft between 30 and 60 mL/min) or severe kidney failure (Cockcroft below 30 mL/min). Polypharmacy (> 5 medications) was also raised. Factors that were likely to disrupt the nutritional assessment were also identified. Patients were considered to be injured when they were suffering from an acute disease with protein reactive C (CRP) concentration > 40 mg/L or when the diagnosis at admission was the treatment of a fracture or acute cardiac or respiratory failure. This CRP limit was chosen in an arbitrary manner by taking into account the clinical habits within our team. The CRP was considered as normal below 10 mg/L. We considered that an increase in the CRP, between 10 and 40 mg/L, may have been a reaction to hospitalization or was the expression of a controlled chronic inflammation, without it being the symptom of a real acute systemic injury. Similarly, a state of dehydration was defined by the presence of clinical signs of extracellular dehydration (skin folds, dry tongue) or, biologically, when the natremia was above 146 mmol/L. Finally, an overhydration was defined by the existence of edema in the legs, clinical signs of biological hemodilution with a homogenous drop in the total protein below 60 g/L, natremia below 135 mmol/L, and hematocrit below 37% in women and 42% in men.

2.3. Nutritional assessment

The nutritional assessment data recorded upon the patient's admission were: the albumin and pre-albumin levels, interpreted in relation to the CRP according to the habits of the practitioners, the search for a previous weight through questioning or in the medical file, allowing the calculation of weight loss over 1 and/or 6 months, the measurement of the current weight and the distance between the heel and the knee to calculate size using the Chumlea equation, then the BMI (Chumlea et al., 1985). The patients were then divided depending on their nutritional status. As required by the French guidelines for nutrition in aging (Haute Autorité de Santé, n.d.), the patients were considered undernourished when the BMI was below 21 kg/m^2, weight loss over 1 month and/or 6 months was above 5 and 10% respectively, or the albumin was below 35 g/L (only 1 criteria sufficed). The albumin level was interpreted as a function of the inflammation represented by the CRP level, in accordance with the clinical practice habits of the department physicians and the HAS. Undernutrition were considered as moderate, but severe when the patient had at least one of the following criteria: BMI below 18 kg/m^2, weight loss over 1 month and/or 6 months above 10 and 15% respectively, or albumin below 30 g/L. Patients presenting an albumin level at the upper limit of a nutritional status and a CRP above 40 mg/L were considered to be in the best nutritional category.

2.4. Bioelectrical impedance analysis

The equipment used was a Nutriguard-M®, Data Input, Germany, at a frequency of 50 kHz. All measurements were performed at the patient's bedside by the same operator, in accordance with the recommendations of the *European Society for Clinical Nutrition and Metabolism* and of the manufacturer (Kyle et al., 2004). For convenience, the measurements were performed on the right-hand side except in some patients where catheters or skin lesions were present. The four electrodes were always of the same model (Ambu White Sensor 0415 M), positioned by the same operator after the skin was cleaned using 60% alcohol solution. Two electrodes were placed on the dorsal surface of the wrist and 2 on the dorsal surface of the ankle, respecting a distance of 5 cm between the 2 electrodes. The variables recorded by the single BIA frequency were: the resistance (R), the reactance (Xc) and the Phase Angle at 50 kHz, calculated according to the formula (11): Phase angle = arctangent (Xc/R) * 180°/π, where Phase Angle is in degrees and the Resistance (R) and the Reactance (Xc) are in ohms.

2.5. Statistical analysis

The population is described, totally and by sexes separated, by the number and associated percentages for qualitative and categorical variables and by the averages ± associated standard deviations or by the median and interquartile range for quantitative variables. Comparisons between groups (Undernourished vs Non-undernourished) were carried out using chi-squared test (or Fisher's exact test when appropriate) for categorical data, and using Student *t*-test (or Kruskal-Wallis test if normality rejected by Shapiro-Wilk's test) for continuous data.

The analysis of undernutrition by phase angle was conducted, for the total population and by sexes separated, with ROC curves looking for a cut-off according to the Youden index (Youden, 1950). The diagnosis values (sensitivity, specificity, positive and negative predictive values) are presented for the selected thresholds. A multivariate logistic regression model was used, for the total population, to analyze the undernutrition as a function of the phase angle, and adjusted for factors that were clinically relevant or statistically significant in univariate analysis. Results are shown as adjusted odd ratio and their 95% confidence interval. In other hand, a conditional inference tree (CTREE) was built and plotted to illustrate the main factors associated with undernutrition, for the total population. All the analyses were performed by formulation for a bilateral p-value of 5% using STATA v12 (Stata Corp, College Station, Texas, USA).