ARTIGO ORIGINAL

Bioelectrical Impedance Phase Angle: Utility in clinical practice

Ângulo de Fase obtido pela Bioimpedância: Utilidade na prática clínica

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ABSTRACT

The choice of the best nutrition assessment method in hospitalized patients remains a challenge. The aim of this study was to review the use of phase angle (PA) in clinical practice. PA is a parameter obtained from bioelectrical impedance analysis, being a derived measure from the relationship between resistance and reactance. Because PA is dependent on body cell mass (BCM) and cell membrane functions, it has been considered a prognostic marker in several clinical conditions. BCM reflects the cellular components responsible for energy transfer and biochemical activity and is considered an excellent reference for expressing the rates of physiological processes, such as energy expenditure and proteolysis. Low PA values suggest cell death or decreased cell integrity, whereas higher PA values suggest a large amount of intact cell membranes, with a consequently better prognosis. The literature lacks studies determining PA reference values, which has prevented its use in routine clinical practice. Reference values are therefore necessary to properly evaluate possible deviations from the population mean.

Keywords: Phase angle; Malnutrition; Nutrition assessment

RESUMO

A escolha do melhor método de avaliação nutricional em pacientes internados ainda se apresenta como um desafio. O objetivo deste trabalho é realizar uma revisão sobre a utilização do ângulo de fase (AF) na prática clínica. O AF é um parâmetro obtido a partir da analise de bioimpedância elétrica, derivado da relação entre as medidas de resistência e reatância. Devido ao fato do AF ser dependente da massa celular corporal (MCC) e das funções da membrana celular, este vem sendo considerado como marcador prognóstico em diversas condições clínicas. A MCC reflete os componentes celulares responsáveis pela transferência de energia e trabalho bioquímico, sendo considerada ótima referência para expressar as taxas dos processos fisiológicos, como o gasto de energia e a proteólise. Baixos valores de AF sugerem morte celular ou diminuição da integridade celular, enquanto AF mais altos sugerem uma grande quantidade de membranas celulares intactas e conseqüente melhor prognóstico. Na literatura, para o nosso conhecimento, ainda há uma enorme carência de estudos que tragam valores de referência para o AF, o que tem impedido a sua utilização. Valores de referência se fazem necessários para avaliar corretamente os desvios que possam ocorrer em relação à média populacional.

Palavras-chave: Ângulo de fase; Desnutrição; Avaliação Nutricional

INTRODUCTION

Hospital malnutrition has been a worldwide reality,[1] affecting 20 to 60% of inpatients,[2] and is closely associated with morbidity and mortality.[3] Malnutrition is characterized by changes in cell membrane integrity and fluid balance.[4] This condition has a multifactorial etiology, including metabolic effects of the underlying disease and dietary deficiencies.[5]

In any case, there is a reduction in lean body mass and subsequent loss of structure and function of organs and tissues that make up lean mass.[6] The goal of nutritional support is to prevent malnutrition from developing into an important cofactor in organ dysfunction. This is possible by providing nutrients in amounts and quality sufficient to match the demands of hypermetabolism, especially protein breakdown.[6]

Historically, nutritional status has been assessed by several methods, including anthropometric (weight, height, circumferences), subjective (subjective global assessment), and laboratory (serum albumin, transferrin, hematocrit, hemoglobin) measurements.[7] However, all of them present a potential limitation to their application.[8]

Bioelectrical impedance analysis (BIA) is a tool that has, as yet, been little used to assess nutritional status.[9,10] This technique is a portable method developed over the past decades that incorporates both morphological and functional assessment.[11]

The phase angle (PA) is a parameter obtained from BIA, being a derived measure from the relationship between resistance (R) and reactance (Xc) measurements.[11] One of the most important issues concerning this measure is whether low PA values may be interpreted as malnutrition or whether PA could be an effective tool for evaluating clinical outcomes or for monitoring disease progression.[12]

BIOELECTRICAL IMPEDANCE IN THE ANALYSIS OF BODY COMPOSITION

BIA is an inexpensive, safe, noninvasive, portable technique for evaluating body composition in clinical practice that has attracted considerable attention over the past 20 years.[13] However, BIA does not measure body composition directly. It measures two bioelectrical parameters: resistance (R) and reactance (Xc).[14]

R is the pure opposition offered by the body to the flow of an alternating electric current,[15] related to extra and intracellular fluid[16] located primarily within lean mass.[17] R is inversely proportional to body water content. In plain terms, water can be regarded as a highly conductive channel with low impedance.[18]

Xc is the opposition offered by the electric flow due to capacitance produced by tissue interfaces and cell membranes,[19] i.e., it reflects the ability of cell membranes to act as capacitors, offering reactance.[17] Xc is related to the cell membrane structure and function,[20,21] i.e., it is related to extra and intracellular water balance, which is dependent on cell membrane integrity.[22]

The relationship between capacitance and R reflects different electrical properties of tissues affected in different ways by disease, nutritional status, and hydration status.[23]

Body composition assessment is based on the flow of an imperceptible electric current (500-800 µA at 50 kHz) through electrodes placed on the hand and foot. After identifying R and Xc levels of the body to electric current, the analyzer measures total body water and, assuming a constant hydration, predicts the amount of lean mass. The main limitation of this method is overhydration, which may overestimate the amount of lean mass.[24] Situations such as physical activity, dietary intake, skin temperature, and menstrual cycle may also directly affect the results, requiring standardized methodologies to optimize these measurements.[23]

The use of BIA has shown to be effective in assessing body compartments in several clinical situations, such as malnutrition, trauma, pre and postoperative periods, liver disease, kidney failure, pregnancy, children, and athletes. However, it is possible to choose an equation that is tailored to the groups under study, thus allowing an individualized interpretation.[25]

BIA suggests prediction equations based on specific models for different types of populations.[24] These equations provide acceptable estimates of fat-free mass, total body water, and bioelectrical impedance measurements.[25] As an alternative to population-specific equations, generalized bioelectrical impedance equations developed for heterogeneous populations, varying in sex and body fat, may be applied.[24]

Table 1 shows some formulas used to calculate fat-free body mass in healthy individuals.

Source: Adapted from Cômodo A et al[27].

PHASE ANGLE

PA is the angle the impedance vector forms relative to the R vector calculated as the arc tangent of the ratio Xc/R in degrees.[11]

PA is formed when a portion of the electric current to which the patient is subjected to is stored in cell membranes, thereby creating a phase shift, which is quantified geometrically as the angular transformation of the ratio capacitance/resistance or PA.[14]

Because PA is dependent on body cell mass (BCM) and cell membrane functions, PA values may change with sex and age. BCM is the metabolically active compartment, composed mainly of muscle. It reflects the cellular components responsible for energy transfer and biochemical activity and is considered an excellent reference for expressing the rates of physiological processes, such as energy expenditure and proteolysis.[4] Changes that may occur in BCM or even functional defects of cell membranes may also result in PA changes.[4]

PA reflects the relative contribution of fluids (R) and cell membranes (capacitance) of the human body. By definition, PA is positively associated with capacitance and negatively associated with R.[18] Low PA values suggest cell death or decreased cell integrity, whereas higher PA values suggest a large amount of intact cell membranes.[11]

The literature lacks studies determining PA reference values, which has prevented its use in various clinical situations. Reference values are therefore necessary to properly evaluate possible deviations from the population mean, as well as to evaluate whether PA may affect outcomes in clinical and epidemiological studies.[20]

PHASE ANGLE IN CLINICAL PRACTICE

PA has been considered a prognostic indicator in several clinical situations, because it may indicate functional changes in the cell membrane and changes in fluid balance.[19,25]

Gupta et al.,[25] evaluating 52 patients aged 29 to 79 years diagnosed with colorectal cancer, found that PA was more effective in assessing survival, when compared to nutrition assessment methods commonly used in clinical practice.

In a different study, Gupta et al.[19] evaluated 58 patients with a mean age of approximately 57 years and a diagnosis of pancreatic cancer and found that PA was an effective tool for the prediction of survival compared to other nutritional indexes.

In 2007, PA was measured via BIA in 2,118 pregnant women in rural Bangladesh. PA values were shown to decrease in advance stage of pregnancy, returning to normal shortly after birth. This nutrition assessment method was not considered contraindicated in this situation.[26]

In 2003, Mushnick et al.[27] evaluated 48 patients undergoing peritoneal dialysis, with a mean age of 51 years, and found that PA was an independent predictor of more than two years' survival, in which patients with PA greater than 6 degrees had a better prognosis.

In HIV-infected patients, with a mean age of 40 years, PA was highly effective in predicting survival and clinical disease progression in this population. Moreover, it was suggested that an increase of PA by 1 degree may represent an up to 29% increase in survival rate.[28]

In 225 patients aged 18 to 80 years and scheduled to undergo elective gastrointestinal surgery in a university hospital in the city of Pelotas, southern Brazil, after adjusting for sex, age, marital status, presence of tumors, and nosocomial infections, PA was the only variable that remained as a prognostic factor.[9]

In patients with liver cirrhosis, low PA values were associated with shorter survival times compared to healthy controls. Among cirrhotic patients, those with PA equal to or less than 5.4 degrees had shorter survival times than patients with PA equal to or greater than 6.6 (±1.4) degrees.[11]

In a study of 81 pediatric patients, aged 1 month to 6 years, PA correlated with body weight and arm muscle circumference in well-nourished children. Malnourished patients showed lower PA values than well-nourished children.[29]

Table 2 shows a summary of the studies previously discussed.

CONCLUDING REMARKS

The biological significance of PA has yet to be well defined. However, in the past decade, several studies have been carried out to investigate the power of PA as an instrument to determine prognostic, nutritional, and cell membrane function values, and also as an indicator of health status in various clinical conditions.

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Table 1. Equations used to calculate fat-free mass (FFM)

Population	Equation
Adults aged 18 to 94 years	$-4.104 + 0.518 \times height^2/R_{50} + 0.231 \times weight + 0.130 \times Xc + 4.229 \times sex$
Elderly	$5.741 + 0.4551 \times height^2/R_{50} + 0.1405 \times weight + 0.0573 \times Xc + 6.2467 \times sex$
Pediatric patients	$0.65 \times (height^2/Z_{50}) + 0.68 \times (age\ in\ years) + 0.15$

Z = Impedance at 50 kHz; Sex = a value of 1 is used for men and 0 for women.

Table 2. Summary of studies previously discussed

Author	Study sample	N	Results
Gupta et al[25]	Patients with colorectal cancer	52	PA was more effective in assessing survival, when compared to commonly used nutrition assessment methods.
Gupta et al[19]	Patients with pancreatic cancer	58	PA was an effective tool for the prediction of survival compared to other nutritional indexes.
Saijuddin et al[26]	Pregnant women	2,118	PA values decrease in advance stage of pregnancy, returning to normal shortly after birth.
Mushnick et al[28]	Patients undergoing peritoneal dialysis	48	PA was an independent predictor of more than two years' survival, in which patients with PA greater than 6° had a better prognosis.
Schwenk et al[27]	Patients with acquired immunodeficiency syndrome	257	PA was highly effective in predicting survival and clinical disease progression in this population.
Barbosa-Silva et al[9]	Patients undergoing gastrointestinal surgery	225	PA was the only variable that remained as a prognostic factor.
Selberg & Selberg[11]	Patients with liver cirrhosis	55	Patients with PA equal to or less than 5.4° had shorter survival times than patients with PA equal to or greater than 6.6°±1.4°.
Nagano et al[29]	Children	81	Malnourished patients showed lower PA values than well-nourished children.

PA = phase angle.