NUTRITION™

Nutrition 21 (2005) 567–573

www.elsevier.com/locate/nut

Applied nutritional investigation

Bioimpedance electrical spectroscopy in the first six months of life: some methodologic considerations

María-Ángeles Sesmero, M.D., Ph.D.[a], Manolo Mazariegos, M.D.[b], Consuelo Pedrón, M.D., Ph.D.[a,*], Joyce Jones, M.D.[b], and Noel W. Solomons, M.D.[b]

[a] *Department of Pediatrics, Hospital Niño Jesús, Madrid, Spain*
[b] *Center for Studies of Sensory Impairment, Aging and Metabolism, Guatemala City, Guatemala*

Manuscript received April 2, 2004; accepted October 5, 2004.

Abstract

Objectives: The objectives of this study were to evaluate the feasibility of using multifrequency bioelectrical impedance spectroscopy (BIS) in newborns and first-semester infants and to assess the influence of diverse methodologic and biological factors on BIS measurements.

Methods: We studied 69 infants of both sexes, from the first day after birth through age 6 mo. They were healthy term infants who had no congenital malformations and were born in a low-income, peri-urban neighborhood of Guatemala City. The design was based on serial, repeated BIS measurements.

Results: Overall mean values of extra- and intracellular resistance (mean ± standard deviation) were 470.0 ± 73.3 Ω and 604.6 ± 179.2 Ω, respectively. We found statistical differences in both resistances in relation to advancing age and degree of movement while taking the measurements. With respect to repeat measurements by two separate observers, interobserver differences were a non-significant 7.6 Ω for both resistances. Restraining the infants and previous consumption of milk or formula had a significant effect on extracellular resistance measurements. The mean standard errors of measurement was 4.5 Ω for extracellular resistance and 73.9 Ω for intracellular resistance.

Conclusion: The BIS technique is feasible in newborn and young children when physiologic and methodologic aspects are respected or controlled.

Keywords: Bioelectrical impedance spectroscopy; Body composition; Total body water; Infants; Guatemala

Introduction

The advent of multifrequency bioelectrical impedance instruments has encouraged the theoretical concept of the partition of total body estimates into extracellular and intracellular compartments. It is necessary to assume that low-frequency current flows through the extracellular space and this condition is questionable and difficult to account for theoretically [1]. Especially in pathologic states, it is important to differentiate intracellular from extracellular water pools [2]. The contraction of the intracellular space with expansion of extracellular water is common to many infections and systemic diseases; this increase in the ratio of extracellular to intracellular fluid is potentially of great utility in monitoring the reciprocal changes in both water compartments. Moreover, with a measurement of bioelectrical impedance across a spectrum of frequencies (bioelectrical impedance spectroscopy, BIS), one can detect intra- and interindividual variations in a more precise manner than with the single-frequency approach. The literature on the application of BIS in adult subjects suggests a promise of being able to differentiate the distinct body fluid compartments in vivo [2,3–8]. Application of BIS to body composition assessment in children has special implications of being an innocuous and non-invasive technique, easy to use, and rapid to apply. The few published studies in healthy children have demonstrated high precision and reproducibility [9]. Some

Support for this study was provided in part by funds from the Genetech Foundation.

* Corresponding author. Tel.: +00-34-91-5-03-59-33; fax: +00-34-91-5-74-46-69.

E-mail address: cpedron.hnjs@salud.madrid.org

0899-9007/05/$ – see front matter
doi:10.1016/j.nut.2004.10.010

investigators have calibrated BIS against dual-energy X-ray absorption and total body potassium (^{40}K) in a multiethnic population of healthy children and found a high correlation with the reference values for estimates of total body and of intracellular and extracellular water when some adjustment constants are applied [10]. Moreover, BIS has been proposed to monitor changes in the hydration state of small children with fluid and electrolyte imbalances [11], protein-energy undernutrition [12], and meningitis [13].

However, many doubts remain in terms of the equivalency of BIS-derived body composition values compared with those obtained with reference methods [14,15]. To the extent that standardization of measurement conditions has been studied, it has been in adults and with monofrequency BIA. To obtain maximal measurement reproducibility, various requisites of standardization have been established such as in the posture of the subject, the positioning of the limbs, the placement of the electrodes, and timing of food intake and exercise before the test [16]. Several of these conditions are difficult to achieve in very small children. Poor tolerance of fasting, lack of voluntary cooperation, the small proportions of the body segments, and physiologic characteristics specific to the young organism have been barriers to the application of bioelectrical impedance methods in early life. Because we found no reports that explored the methodologic caveats of BIS when applied to very young infants, we decided to design and conduct research oriented to standardizing BIS in this age group. The objectives of the present study were to evaluate the feasibility of performing BIS measurements in newborns and young infants to study the effect of diverse methodologic factors, analyze the effect of advancing age during the first 6 mo of life, and calculate the measurement error.

Materials and methods

Subjects

Sixty-nine infants, 32 males and 37 females, ages 0 d to 6 mo, were enrolled. All were healthy, had no congenital malformation, and were born in a peri-urban neighborhood in metropolitan Guatemala City.

Methods

Bioelectrical impedance spectroscopy

We used the Hydra Bioelectrical Impedance Spectroscope ECF/ICF, Bioimpedance Analyzer 4200 (Xitron Technologies, San Diego, CA, USA). We analyzed two parameters: extracellular resistance (Re) and intracellular resistance (Ri), derived from Cole's model. Dual consecutive measurement series were used in all subjects studied. Children were placed in the supine, decubitus position on the non-conductive surface of a sponge-rubber cushion. The subjects remained clothed, with only the distal portions of the right arm and leg extremities being uncovered. We wiped isopropyl alcohol over the skin sites and let it dry before applying the 1.8- × 8.7-cm electrode patches (Xitron IS4000 Bioimpedance Electrode, Xitron Technologies).

The placement of the electrodes for the upper right limb were as follows: the center of the transmitter (signal) electrode, which was the source of the alternating current impulses of varying frequencies, was placed on the volar surface of the forearm at the wrist, precisely at the union of the styloid epiphysis of the radius and the cubitus bone, whereas the upper edge of the sensor electrode was attached 3 cm above the former on the volar surface of the forearm. The positioning of the electrode on the lower right limb was as follows: the center of the signal electrode was placed on the anterior surface of the ankle at a spot exactly midpoint between the external and internal malleoli. In this way, the distance between the centers of the two electrodes on each extremity was 4.8 cm. The electrode placement was reinforced with adhesive tape to avoid displacement and ensure firm contact throughout testing. We ensured that there was no contact of the electrode cables with one another or with any metallic surface.

In the experiment designed to analyze the effect of interelectrode distances, we explored a series of graded alterations in placement of the electrodes on the limbs. The upper and lower limbs were kept in 30- to 40-degree abduction with respect to the trunk, taking into consideration the inevitable fact that physiologic flexion at birth is less than that at ages of 2 to 6 mo. To obtain immobility and abduction and semi-extension of the limbs, the child was wrapped in a baby blanket and the observer exerted light pressure on the extremities, on the top of the blanket, and without making direct skin contact with the subject.

In one of the experiments, we analyzed the comparative effects on BIS measurement of first restraining and then not restraining the subjects in two consecutive evaluations. We used the following rating scale to quantify the degree of the subject's movement during the BIS measurement sessions: 0, complete absence of movement; 1, mild and brief movements; 2, intense but brief movements; 3, constant movement, from mild to intense; and 4, crying.

Experimental design

In the first experiment, we enrolled 26 children (12 boys and 14 girls) who were distributed by five age groups: younger than 24 h (n = 5), 6 to 9 d (n = 6), 2 mo (n = 5), 4 mo (n = 5), and 6 mo (n = 5). Within or across all groups we analyzed age, movement, measurement error, intraobserver variability, interobserver variability across two standardized observers, effect of restraint, and placing, removing, and replacing the electrodes in position. Hence, in this experiment, each subject underwent 16 BIS determinations (with and without restraint and with first and second electrode placements, all in duplicate measurements and each by each of the two observers).

In the second experiment, to evaluate the effect of consumption of a known volume of milk, we enrolled 29 infants