# THE USE OF BIOELECTRICAL IMPEDANCE ANALYSIS IN NEWBORNS. THE NEED FOR STANDARDIZATION

Agnès Gartner[1], Bernard Maire[1], Francis Delpeuch[1], Pierre Sarda[2], Renée Pierre Dupuy[2], and Daniel Rieu[2]

[1] Laboratoire de Nutrition Tropicale, Département Santé, ORSTOM, B.P. 5045, 34032 Montpellier Cedex, France
[2] Service de Pédiatrie II, Hopital St Charles, 34059 Montpellier Cedex, France

## INTRODUCTION

Rapid growth occurs during fetal and neonatal development. The duration and quality of intrauterine development affect neonate body composition. Weight is routinely used to assess and monitor the nutritional status of newborns. Any weight loss or gain in hospitalized newborn infants may reflect shifts in water balance rather than changes in body mass, and have strong implications for investigating the nutritional status of newborns. It is, however, difficult to measure the body composition of newborns. Bioelectrical impedance analysis (BIA) is a relatively new technique for estimating body composition. It is based on the fact that the conduction of an applied electrical signal is far greater in fat-free tissues (because of water and electrolyte content) than in fat. BIA has been gaining wide usage for the estimation of body composition in adults[1,2], and should be a very suitable method for use in children, because of its noninvasiveness, simplicity and reliability.

No mathematical equation can be applied to young children to transform BIA results into body composition variables. Calculation of the lean and fat content from measurement of body weight and BIA implies a constant relation between body water and lean body mass, but present measurements in neonates do not support this assertion. Few studies using BIA have been performed in newborns. A relation between length$^2$/R and the volume of body water has been postulated in the newborn[3,4]. Assuming this relation to be true, BIA measurements provide a useful tool in perinatal body water and nutrition studies.

The purposes of our study with newborns were to determine the reliability of the method, to show the influence of electrode position on the result and to compare and contrast the anthropometric and BIA status of small- or appropriate-for-gestational-age newborns at birth and at 3 weeks of age.

*Human Body Composition*, Edited by K.J. Ellis and J.D. Eastman, Plenum Press, New York, 1993

## BIOELECTRICAL IMPEDANCE ANALYSIS AND ANTHROPOMETRY

BIA measurements were recorded using a BIA/101S unit (Akern, Florence, Italy, RJL System licensee) which uses a tetrapolar electrode configuration. BIA measurements were taken with the subject lying down, legs slightly apart to avoid contact, and arms held away from the body. The disposable adhesive-backed electrodes were placed on the right hand side of the body. We chose to place the signal electrode on the dorsal side immediately above the flexure of the wrist, and the sensor electrode 6 cm along the forearm; the leg signal electrode was placed on the dorsal side of the ankle immediately above the intermaleolar line and the sensor electrode 6 cm away in the pre-tibial region[5]. The child was comforted and pacified, if necessary, and the arm or leg was held using a cloth to avoid operator's skin contact that led to a reduction in resistance (R) (data not shown). When a consistent, unvarying reading for R was registered on the digital meter, it was recorded. R was also expressed in the form length$^2$/R because that is a function of total body water volume conventionally used to express BIA measurements.

Nude weight was reported to the nearest 0.01 kg and crown-heel length was measured in supine position, to the nearest 0.5 cm.

All results are expressed as mean ± SD. To compare the mean result in the 2 groups, statistical analysis was performed using Student's t test. A value of $p<0.05$ was considered statistically significant.

## RELIABILITY STUDY

All replicate measurements of BIA were made within a 30-minute period, during which newborns were of course moved and repositioned. A first test-retest sudy was performed by the same observer with electrodes kept in place (n=67). A second test-retest study was performed by the same observer by repositioning the 4 electrodes between the replicate measurements (n=22). For the evaluation of inter-observer reliability, 12 newborns were assessed by both observers. The formula used for estimating technical error of measurement is $\sqrt{\Sigma d^2/2n}$ where d is the difference between two observations, n is the number of pairs of observations. Percentage reliability is the technical error x 100/overall mean of the measurements.

In the reliability studies, BIA results gave a coverage of the whole range of measurements. Test-retest trials showed a good reliability percentage of 2.2, 2.3, and 2.6% with electrodes kept in place, repositioning of the 4 electrodes, and 2 observers, respectively, for the R measurement in the population of newborns studied.

## INFLUENCE OF ELECTRODE POSITION

First, a test-retest study was performed, as in the reliability study, to compare replicate measurements being made with 6 and 5 cm between the electrodes (n=22). When the sensor electrode was intentionally moved by 1 cm on each limb, the reliability percentage of R measurement was 9.1%. The mean proportion of the difference between R observed with 6 and 5 cm between the electrodes, as compared with basic measurement (distance of 6 cm between the electrodes), was 13.3 ± 2.2%. These results showed the importance of a correct electrode positioning.

However, no standard position has yet been established in young children, and it is of great importance to consider this parameter. Because impedance is related to the length of the conductor, the measurement of R is therefore closely linked to the position of the electrode pairs. The standard sites used in adults are too close together

when used on the hand and foot of newborns and can lead to an interaction between the electrodes in each pair. The few published studies in newborns in this field were performed using different application sites[3, 4, 6] and are not comparable.

The positioning of the various electrodes has never been tested in newborns. To perform these tests we positioned the electrodes as for adults (position 1 at the base of the fingers and along the metacarpal joint, and position 2 on the wrist and ankle) and added six electrodes side by side on the arm and leg in fixed, numbered (3 to 8) positions. The electrodes were 1.2 cm wide. Our test showed, as previously reported[5], that the farther the selected sensor electrode from the fixed signal electrode (position 1), the more R values decreased. The interaction tested with the sensor electrode in position 8 disappeared as soon as the signal electrode moved toward the fingers. In conclusion, electrode position, and above all the position of the sensor electrode, is one of the most critical factors in BIA measurements. Standard electrode positions in young children have now become indispensable.

## STUDY ON SMALL- AND APPROPRIATE-FOR-GESTATIONAL-AGE NEWBORNS

BIA and anthropometric measurements were performed in a pediatric care unit on 62 newborns hospitalized at birth. Gestational age was calculated in terms of completed weeks of gestation from the first day of the mother's last menstrual period, and confirmed with early fetal echography. Subjects were divided into 2 groups: small-for-gestational-age (SGA) or appropriate-for-gestational-age (AGA), with birth weight below or above the 10$^{th}$ percentile of the reference value[7], respectively. Measurements were performed on 35 SGA and 27 AGA in the first few days after birth, and for a subgroup (21 SGA and 11 AGA) again about 3 weeks later. BIA measurements were taken by the same person. BIA and anthropometric measurements were always performed early in the morning on infants stretched to their full length inside the incubator or on a table with mattress. Results are reported in Table 1.

**Table 1.** Anthropometric and BIA measurement (mean ± SD) of SGA and AGA newborn infants.

| | Birth | | Age 3 weeks | |
|---|---|---|---|---|
| | SGA (n=35) | AGA (n=27) | SGA (n=21) | AGA (n=11) |
| Age (days) | 3.1 ± 1.7 | 2.4 ± 1.2[d] | 18.6 ± 6.5 | 19.0 ± 7.6[d] |
| Weight (kg) | 1.818 ± 0.249 | 2.470 ± 0.657[c] | 2.111 ± 0.158 | 2.497 ± 0.456[b] |
| Length (cm) | 43.2 ± 1.9 | 46.2 ± 3.5[c] | 45.2 ± 1.4 | 47.2 ± 1.7[a] |
| Resistance (ohms) | 439 ± 55 | 364 ± 62[c] | 432 ± 51 | 419 ± 60[d] |
| Length$^2$/R (cm$^2$/ohms) | 4.3 ± 0.6 | 6.1 ± 1.3[c] | 5.0 ± 0.6 | 5.7 ± 0.8[d] |

[a] $p<0.05$, [b] $p<0.01$, [c] $p<0.001$, [d] non significant versus SGA group

The two groups studied at birth had similar mean age and mean gestational age at birth. There was a significant difference between the two groups in weight and length, and also in tricipital and subscapular skinfold thicknesses and mid-upper arm and thigh circumferences (data not shown); the higher values were in the AGA group. BIA values were significantly different between the 2 groups in the first days of life with higher R values and lower length$^2$/R values in SGA newborns (Table 1). Some R and length$^2$/R values were tested as threshold of discrimination of the 2 groups at birth. For R=410 ohms as threshold, sensitivity, specificity and positive test predictive value were 65.7, 88.8 and 88.4%, respectively. For length$^2$/R=5.2 cm$^2$/ohms as threshold, sensitivity, specificity and positive test predictive value were 94.3, 76.0 and 84.6% respectively. The index length$^2$/R enabled a better prediction than R alone.

Whereas all anthropometric parameters during the 3 weeks increased concomitantly, BIA values showed different evolution in the 2 groups. BIA values were similar for the 2 groups at 3 weeks of age, however (Table 1).

BIA measurements showed that the body composition of SGA newborns was disturbed at birth, and that evolution was different from that in AGA newborns. The decrease of body water that occurs after birth in healthy newborns was detectable by the increase in R in the AGA newborns. BIA parameters returned to values similar to those in the AGA group during postnatal growth of SGA newborns. This phenomenon was not visible with anthropometric measurements alone. These preliminary results suggest that BIA could be useful as a noninvasive method to assess the adequacy of body composition during the early growth of SGA newborns. Standardization of the method, however, is necessary to allow R values to be compared and thus increase interest in studies using BIA in young children.

## REFERENCES


1. H.C. Lukaski, W.W. Bolonchuk, C.B. Hall, and W.A. Siders, Validation of tetrapolar bioelectrical impedance method to assess human body composition, J Appl Physiol 60:1327 (1986).
2. R.F. Kushner, and D.A. Schoeller, Estimation of total body water by bioelectrical impedance analysis, Am J Clin Nutr 44:417 (1986).
3. P.B. Muthappa, J.C. Morkeberg, W.W. Wong, R.J. Schanler, and H.P. Sheng, Rapid, noninvasive measurements of body composition using bioelectrical impedance in preterm infants, Pediatr Res 27:287A (1990).
4. S.R. Mayfield, R. Uauy, and D. Waidelich, Body composition of low-birth-weight infants determined by using bioelectrical resistance and reactance, Am J Clin Nutr 54:296 (1991).
5. A. Gartner, B. Maire, F. Delpeuch, P. Sarda, R.P. Dupuy, and D. Rieu, Importance of electrode position in bioelectrical impedance analysis, Am J Clin Nutr 56:1067 (1992).
6. C. Grazioso, S. Molina, M.C. Santizo, M. Mazariegos, M.L. Siu, C. Vettorazzi, and N.W. Solomons, Anthropometry and bioelectrical impedance analysis in newborns with intrauterine growth retardation, *in*: "Advances in In Vivo Body Composition Studies", S. Yasumura, J.E. Harrison, K.G. McNeil, A.D. Woodhead, and F.A. Dilmanian, eds., Plenum Press, New York (1990).
7. B. Leroy, F. Lefort, A propos du poids et de la taille des nouveaux-nés à la naissance, Rev franç Gynéc 66:391 (1971).

# Human Body Composition

## *In Vivo* Methods, Models, and Assessment

Edited by

Kenneth J. Ellis and Jerry D. Eastman
Baylor College of Medicine
Houston, Texas

Plenum Press • New York and London