ASSESSMENT OF FLUID BALANCE IN NEONATES USING BIOIMPEDANCE ANALYSER

D. O. Mendonça[1], E. J. B. Zaeyen[2], M. N. Souza [3], *Member, IEEE*
[1]Biomedical Engineering Program, Rio de Janeiro Federal University, Rio de Janeiro, Brazil
[2]Central Hospital of Military Police of Rio de Janeiro, Rio de Janeiro, Brazil
[3]Electronic Engineering Department E.E, Rio de Janeiro Federal University, Rio de Janeiro, Brazil

***Abstract*- The amount of liquid intake in neonatal care should be preceded by the knowledge of the neonate hydro-balance. A reduced liquid intake can cause dehydration, electrolytic unbalance and hypotension. By the other hand, an excessive intake can cause peripheral edema, congestive heart failure, among others problems. Thus, the assessment of the liquid compartment in neonates, by a non-invasive, non-expensive and fast method can contribute to increase the quality of the neonatal care. Bioimpedance has been used to assess fluid volumes in adults, but a very few works has been published in neonatal studies, specially using techniques able to observe the intra and extra-cellular compartments separately. The present work aims to study the fluid balance in neonates using a recent bioimpedance spectroscopy method and correlate the results with clinical findings.**

***Keywords*-Total Body Water, Bioimpedance Analyze, Fluid Balance, Neonates.**

I. INTRODUCTION

The neonatal care has a strong influence on the child survive and development. They need different amount of fluids and it is important to analyze the individual balance of fluids to give them the liquids they need. A reduced liquid intake can cause dehydration, electrolytic unbalance and hypotension. On the other side, an excessive intake (more than 170ml/Kg/day) can cause peripheral edema, congestive heart failure, bronchopulmonary dysplasia, necrotizing enterocolitis, cerebral intraventricular hemorragy and possible symptomatic patent ductus arteriosus [1].

The preterm neonate (birth at gestational age less than 37 weeks) has a percentage of total body water (essentially extracellular water) higher than the term (birth at gestational age more than 37 weeks). This disproportion is due to the transference of extracellular water to the intracellular compartment that occurs during the pregnancy. In the first sixteen weeks of pregnancy, the total body water is 90% of fetal weight and the proportion of extracellular and intracellular water is 65% and 25%, respectively [1]. In the term, this compartments change to 45% and 35% of total body weight, respectively [1] and the total body water constitute 80% of weight [2]. This alteration in the body fluids shows that the total body water and extracellular water diminish with the increase of gestational age. This liquid reduction constitutes a body weight loss. Therefore, it is expected a higher weight loss in low birth weight neonate. Usually, the full-term neonate loses 10 to 15% of birth weight and the preterm can lose up to 20% [3].

There are some studies that correlate the change of weight with the prediction of total body water. Nevertheless, this relation can not detect the changes in intra and extra cellular volume [1, 4]. So, due to the changes that can occur in the extracellular volume without total corporal volume alteration, the weight is not a confident parameter to monitor the fluid balance. Moreover, due to different variables that can affect the fluid compartments in neonates, the liquid requirements must be based on the need of each baby. So, a non-invasive technique to measure the cellular compartments volume and total body water can contribute to the assistance of the neonatal care.

The aim of this paper is to monitor the intra / extra cellular fluids and total body water of neonates with a Bioimpedance Spectroscopy Analyzer (BISA), based on a step response [5] and that supply the same bioimpedance parameters the Multiple Frequency Bioimpedance Analyzer (MFBIA) supplies, and correlate the results with clinical findings.

II. METHODOLOGY

The method of getting whole body bioimpedance parameters proposed by Neves & Souza [5] is based on a current response to a voltage step excitation. The principal advantage of this method is the use of a smaller number of signals to characterize the bioimpedance, since only one excitation signal scans all frequency's components.

According to the system utilized by the authors, the current behavior can be express by the equation 1. The current response is composed by two exponential, where the fast is associated to the membrane capacitance and the slowly to the electrode capacitance.

$$i(t) = i_p[(k_1 e^{p_1 t}) + (k_2 e^{p_2 t})] \qquad (1)$$

where i_p, k_1, k_2, p_1 and p_2 are constants associated with the bioimpedance parameters.

With the expected equation for the current *i(t)* and an analogue version of it, experimentally obtained, the electric parameters of bioimpedance like R_e (extracellular resistance), R_i (intracellular resistance), C_m (membrane capacitance) and C_e (electrode capacitance) are extract using a multiparametric optimization procedure. The implemented algorithm is based on a steepest descend gradient method to obtain the best parameters that adjust of theoretic expectation to the experimental data. Beside the basic bioimpedance parameters

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Abstract

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mentioned above, the system also supplies ordinary parameter supplied by the MFBIA, which is related to the TBW [6], it is the R_{inf} (parallel association between R_e and R_i).

The bioimpedance measurements of the present work have been obtained by a prototype instrument based on the principle described above and that was developed in the Biomedical Instrumentation Laboratory of Biomedical Engineering Program at the Federal University of Rio de Janeiro, Brazil. The current response acquisition and the applied step voltage are generated through an acquisition card (National® PCM-CIA, DAQCard AI-16E-4 model) mounted in a laptop framework.

The data acquisition is performed through a specific program that has been developed in LabVIEW® 6i (National Instruments).

The user's interface of such system can be seen in Fig.1.

The extraction of the MFBIA electric parameters (R_e, R_i, C_m e C_e) and the correspondents Single-Frequency Bioimpedance Analyzer (SFBIA) (R_x and X_{Cx}) proceeds after data fitting (figure 2).

After the obtaining of the bioimpedance parameters the neonatal total body water (TBW) and extracellular water (ECW) can be estimate through regression equations found in literature [7, 8, 9, 10, 11, 12], that normally use both bioimpedance and anthropometric measurements. The intracellular water (ICW) is calculated subtracting the extracellular water from the total body water. Although some of those equations have been validated against gold standards methods, they are dependent of the studied population. In the present stage, the present work does not aim to develop a new regression equation and to estimate values to the liquid comportment. Just bioimpedance values are measured and analyzed based on their behavior against clinical findings.

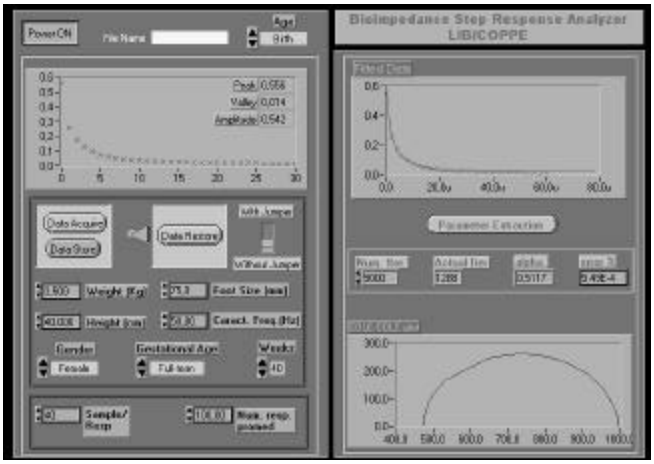

Fig. 1 – The user's interface of the developed bioimpedance spectrocopy system showing the signal acquisition part (left) and current response curve fitting part (right).

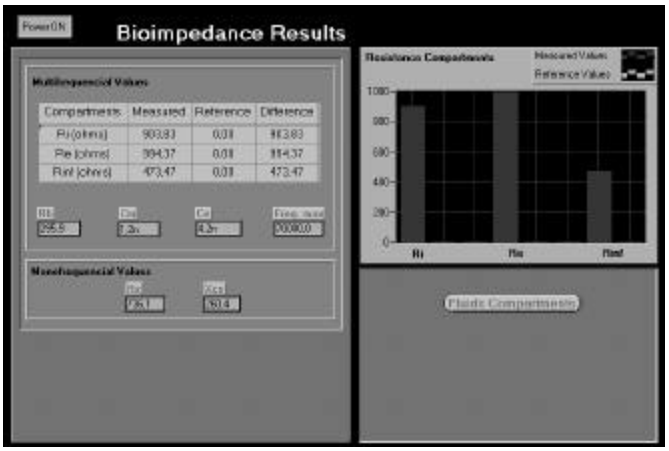

Fig. 2 – MFBIA electric parameters (R_e, R_i, C_m e C_e) and SFBIA electric parameters (R_x and X_{Cx}).

A. Subjects

The bioimpedance and anthropometric measurements were performed in 18 full-term neonates (38,9 ± 1,4 gestational age) of both genders, in the periods of the first 24 hours, and between 24 and 48 hours. Until now only three neonates were measured at the period of 10 days after birth. It must be mentioned that those neonates with any pathology that can change the intra and/or extracellular compartments (renal dysfunction, congestive heart failure, sepsis, and dehydration) were excluded from the data.

This study was accepted by the Scientific Ethic Committee of the Central Hospital of Military Police of Rio de Janeiro (RJ, Brazil) and informed consent was obtained from the parents of the children.

B. Bioimpedance and Anthropometric Measurements

The weight was measured in a digital scale (Urano®) to the nearest 0.005 kg. The height is measured to the nearest 0.01m by a stadiometer and the neonate's foot measured by a Cescorf® caliper to the nearest 1 mm.

The bioimpedance measurements were made with a bipolar electrode array using Ag/AgCl disposable adhesive electrodes (3M Red Dot 2258-3 - neonatal). According to Neves & Souza [5], it is not necessary the use of four electrodes if the skin-electrode impedance were included on measurements systems.

The electrodes were placed at the pisiform prominence of the wrist and between the malleoli lateral and medial at the ankle. The remotion of stractum corneum is performed in a standard procedure of 10 scratches with gauze and alcohol, in order to avoid difference in the bioimpedance measurements.

The neonate was positioned in dorsal deceit and the data acquisition was performed when the newborn was in a quiet position. If necessary, an operator using latex gloves held it, in order to avoid direct contact with the skin of the neonate. All acquisitions were performed before breast-feed.

III. RESULTS

The anthropometrics measurements (weight and height) are shown in table I. Values of R_i, R_e, R_{inf} can be seen in the tables II, III and IV, respectively.

The results are shown in the form mean ± standard deviation. Statistical significance was considered under p<0,01.

TABLE I
ANTHROPOMETRIC MEASUREMENTS (MEAN ± SD) IN THE 24 HR, 48 HR AND 10 DAYS AFTER BIRTH

	24 hours	48 hours	10 days
Weight (kg)	3.14 ± 0.38	2.95 ± 0.36	3.45 ± 0.29
Height (cm)	49.67 ± 1.57	49.67 ± 1.57	50.00 ± 2.65

TABLE II
INTRACELLULAR RESISTANCE IN 24 HR, 48 HR AND 10 DAYS AFTER BIRTH

	Intracellular Resistance (Ω)		
Subject	24 hours	48 hours	10 days
1	2369.28	2538.82	2557.68
2	1923.44	2521.85	
3	2249.86	2266.22	2376.33
4	1986.39	2191.63	
5	1966.70	2206.15	2493.62
6	1962.28	2264.11	
7	2602.77	2678.25	
8	2154.66	2650.14	
9	2187.49	2216.77	
10	1483.50	2297.52	
11	1907.20	2428.29	
12	1761.53	2242.32	
13	1805.29	2114.59	
14	2329.44	2277.36	
15	1502.04	1740.77	
16	2292.12	1966.31	
17	1903.26	2149.72	
18	1458.61	1820.05	
Mean	1991.44	2253.94	2475.88
SD	320.19	253.83	91.97

TABLE III
EXTRACELLULAR RESISTANCE IN 24 HR, 48 HR AND 10 DAYS AFTER BIRTH

	Extracellular Resistance (Ω)		
Subject	24 hours	48 hours	10 days
1	1438.62	1224.64	1168.71
2	1411.99	1101.09	
3	1182.67	1437.00	1265.8
4	923.36	973.47	
5	943.94	1194.45	1103.23
6	978.73	1458.81	
7	1049.38	1062.85	
8	1060.38	1049.77	
9	1133.15	1209.93	
10	1065.86	1303.33	
11	1295.79	1473.41	
12	980.79	1543.19	
13	1261.65	1114.43	
14	898.5	989.89	
15	1179.65	1168.3	
16	1172.52	1419.22	
17	1125.26	1073.39	
18	1145.74	1022.01	
Mean	1124.89	1212.18	1179.25
SD	156.80	183.94	81.80

IV. DISCUSSION

Table I shows that between the birth and the first 48 hours of life, all neonates lost weight (0.190 ± 0.060 kg, p<0.01). However, all of them increased their weight (0.570 ± 0.09 kg, p<0.01) between the measure made in the first 48 hours and 10 days after birth.

TABLE IV
INFINITY RESISTANCE EXTRACTED IN 24 HR, 48 HR AND 10 DAYS AFTER BIRTH

	Infinity Resistance (Ω)		
Subject	24 hours	48 hours	10 days
1	895.11	826.14	802.17
2	814.25	766.45	
3	775.19	879.39	825.88
4	630.35	674.06	
5	637.81	774.90	764.85
6	653.02	887.18	
7	747.86	760.89	
8	710.65	751.92	
9	746.47	782.72	
10	620.23	831.59	
11	771.57	917.63	
12	630.01	914.10	
13	742.64	729.81	
14	648.40	689.98	
15	660.73	699.10	
16	775.71	824.28	
17	707.17	715.92	
18	641.69	654.49	
Mean	711.60	782.25	797.63
SD	77.24	82.09	30.77

It is known the bioimpedance, specially its resistive part, is inversely related to the volume [9]. Therefore, an increase in the resistance must correspond to a decrease in the volume.

Analyzing the resistance differences between 24 and 48 hours one can see that the value of *Rinf* presented a statistically significant increase (p<0.01) of about 93.42 ± 89.12 Ω in 15 children and a non-statistically significant decrease (p>0.05) of 43.20 ± 28.35 Ω in 3 children. The *Ri* parameter increased about 318.93 ± 217.81 Ω (p<0.01) in 16 children and decreased 188.95 ± 193.56 Ω (p>0.05) in 2 children, while *Re* parameter increased 221.90 ± 172.72 Ω (p<0.01) in 11 children and decreased 124.24 ± 111.29 Ω (p>0.05) in 7 children.

Among the 15 neonates that had their *Rinf* increased, 9 also increased *Ri* and *Re* values (differences of 298.17 ± 265.18 Ω, p<0.01; 233.64 ± 186.90 Ω, p<0.01, respectively). Such findings seem reflect the children lost TBW, including ICW and ECW. Either, four children increased *Ri* (differences of 335.53 ± 120.50 Ω, p<0.01) and decreased the *Re* parameters (differences of 49.39 ± 53.18 Ω, p>0.05). It can be interpreted as the children lost TBW, probably with water transference from the intracellular to extracellular compartment.

Those children who showed a decrease in *Rinf* (differences of 43.20 ± 28.35 Ω) increased the *Ri* (359.08 ± 218.73 Ω, p>0.05) value and decreased *Re* (224.03 ± 82.30 Ω, p<0.05). Although some differences are non-statistically significant, those alterations can be explained by the water transference

from the intracellular to the extracellular compartment. As the expected behavior to this children would be the lost of TBW, since they lost weight, a possible reason is the liquid intake just before the data acquisition.

Comparing the results of 10 days with the first 48 hours of life, the 3 studied children decreased *Rinf* and *Re* parameters (differences of 29.18 ± 22.19 Ω, $p<0.05$; 106.12 ± 59.06 Ω, $p<0.05$, respectively) and increased the *Ri* (differences of 138.81 ± 136.59 Ω, $p>0.05$). These values indicate an increase of TBW that was followed by an increase of body weight (differences of 0.570 ± 0.09 kg, $p<0.01$) and the extracellular water. Although the increase in *Ri* can not considered statistically significant, the volume of the intracellular compartment seems continue to decrease. Such results are in agreement with Fomon [13] that reported the full-term neonates, differently of adults, have an extracellular volume higher than the intracellular. This proportion reverses after three years old. Therefore, it is expected that child intra-cellular volume remains less than the extra-cellular until such age. This behavior can be related to kidney's development, that is, the effective number of functional nephrons.

V. Conclusion

The present paper showed the use of a new spectrocopy bioimpedance technology in the assessment of fluid balance in neonates. Is must be mentioned that there are very few works in the literature concerning the values of the range of normal values of bioimpedance parameters to such type of study, being the majority obtained with SFBIA. Then, it is still necessary to perform studies with MFBIA or equivalent techniques, as the presented in this paper, to get information concerning the intra and extra-cellular compartment, and not just the total body water.

The conversion of the electrical indexes (*Re*, *Ri*, and *Rinf*) into biological indexes (ECW, ICW, and TBW), through regression equations found in the literature, and the statistical validation with higher number of neonates is actually in course.

It is our guess that a better understanding of the fluid balance in neonates, by a non-expensive, fast and non-invasive technique, helps to increase the quality of the neonatal care.

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