Multifrequency bioelectrical impedance analysis in women with a normal and hypertensive pregnancy[1,2]

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ABSTRACT

Background: An increase in total body water is common in normal pregnancy. It is thought to be an important mechanism of maternal adaptation to pregnancy.

Objective: The aim of the present study was to assess longitudinal changes in body water compartments in pregnant women and to correlate these measurements with the course of pregnancy.

Design: One hundred seventy-three pregnant women with apparently normal, single pregnancies participated in this longitudinal study. Anthropometric measurements and multifrequency bioelectrical impedance were performed during the first, second, and third trimesters of pregnancy.

Results: One hundred three of the women completed all of the measurements; 50 of the women had a normal pregnancy and 13 had gestational hypertension. Total body water, extracellular water, and intracellular water values in normal pregnancies showed a significant, progressive increase throughout pregnancy. In women with gestational hypertension, total body water, extracellular water, and intracellular water values showed an opposite trend, suggesting a lack of plasma volume expansion through fluid-retention mechanisms.

Conclusions: Our results show that multifrequency bioelectrical impedance analysis can be used to monitor variations in body water compartments in normal pregnancy and detect gestational hypertension. *Am J Clin Nutr* 2000;72:780–3.

KEY WORDS Pregnancy, multifrequency bioelectrical impedance analysis, gestational hypertension, body composition, women

INTRODUCTION

Changes in body composition during pregnancy and their effects on pregnancy outcome represent a field of major interest in perinatal medicine. Classic methods of body water assessment (eg, isotope dilution with deuterium or oxygen−18) are too expensive and complicated and subsequently have low patient compliance. Multifrequency bioelectrical impedance analysis (MF-BIA) allows the determination of body composition, ie, total body water (TBW), fat mass, and fat-free mass. MF-BIA is based on the body's conduction of variable frequency (multifrequency) to electrical current to determine total conductor volume of the body. Because water and electrolytes are the determinants of electrical conduction in the body, TBW is easily evaluated by BIA. Many studies validated the use of this method for estimating TBW in humans (1–4).

It was shown that human pregnancy is associated with an increase in blood volume, which has proven to be an increase in plasma volume relative to red blood cell mass (5). Because plasma volume expansion can directly affect TBW, it is reasonable to suggest that BIA variables could predict TBW. Studies in nonobese and obese adults identified BIA variables [resistance (R) and reactance] as significant predictors of TBW (6). Reactance was shown to be a unique predictor of extracellular water (ECW) and can explain TBW-prediction variabilities (as measured with dilution techniques) in pregnant and in nonpregnant women (4, 7). Changes in maternal body weight and TBW reported in various cross-sectional (8–10) and longitudinal (11–13) studies ranged from 9.2 to 14.3 kg and from 6.3 to 8.5 L, respectively. The relative contribution of water to observed weight gain ranged from 50% to 70%. The increase in TBW could be monitored by tetrapolar BIA.

The increase in TBW in pregnancy is important to clinicians. Fetal and placental development, increases in amniotic fluid volume, and changes in maternal blood cause increases in TBW. The increase in TBW is responsible for a large proportion of weight gain during pregnancy. Additionally, a common finding in pregnancy is various degrees of edema, indicating an increase in the ECW volume. Few studies of changes in body fluids during pregnancy have been conducted because of the accompanying difficulties, ie, such studies are too laborious and invasive for pregnant women. Important advances in the development of noninvasive techniques for assessing TBW have been made. One of these techniques is MF-BIA.

The aim of this study was to assess longitudinal changes in ECW and TBW in a group of pregnant women periodically during pregnancy—during the first, second, and third trimesters—and to correlate these measurements with the course of pregnancy.

TABLE 1
Clinical data of the women with a normal pregnancy (control group) and those with gestational hypertension[1]

	Control group (n = 50)	Hypertensive group (n = 13)
Age (y)	32.00 ± 4.00	34.20 ± 5.90
Body weight (kg)	63.60 ± 10.70	77.10 ± 16.80
Height (cm)	160.30 ± 6.56	159.00 ± 6.59
Time of delivery (wk)	39.00 ± 1.71	36.70 ± 3.19
Neonatal weight (g)	3203.00 ± 510.60	2637.00 ± 952.40
Apgar score		
At 1 min	8.34 ± 0.99	7.90 ± 1.70
At 5 min	9.56 ± 0.54	9.30 ± 0.90

[1] $\overline{x} \pm$ SD.

SUBJECTS AND METHODS

Subjects

The study was performed in 173 pregnant patients with apparently normal, single pregnancies. All of the women reported their usual menstrual periods to be normal (frequency: 28–32-d cycle). Pregnancy was documented with a positive plasma β-human chorionic gonadotropin test. This study was conducted in the Obstetric and Gynecologic Department at the University of Tor Vergata, Rome. The Human Subjects Committees of the University approved the study, and each subject gave her written, informed consent before participation.

Experimental design

MF-BIA measurements were performed in each subject at 3 time points during pregnancy: the first trimester (between weeks 9 and 13), the second trimester (between weeks 16 and 24), and the third trimester (between weeks 32 and 36). The subjects were instructed to consume their usual diets and to refrain from strenuous physical activity on the day before the tests. After an overnight fast, the women came to the laboratory for measurements of standing height and body weight with a stadiometer and a calibrated scale, respectively. Subsequently, on the same day, MF-BIA was performed and hematocrit was evaluated with use of a standard method and instrumentation.
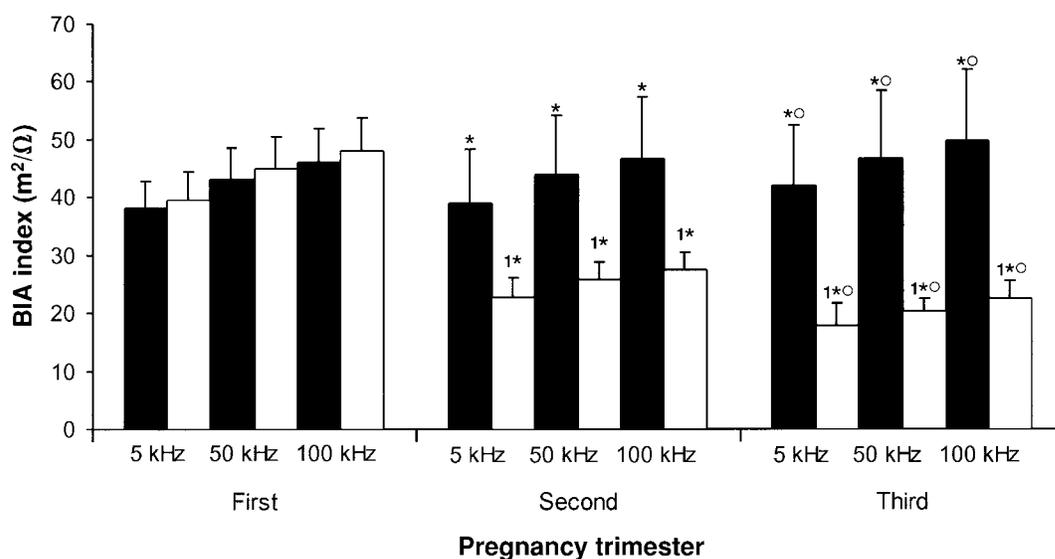
Bioelectrical impedance

Determination of bioelectrical impedance was made by using a tetrapolar multifrequency impedance analyzer (Human IM Scan; Dyetosystem, Milan, Italy). The women, clothed but wearing no shoes or socks, lay supine on a table made of nonconductive materials while the measurements were performed as described previously (14, 15). Bioelectrical impedance was measured at specified frequencies: 5 kHz (BIA_5), 50 kHz (BIA_{50}), and 100 kHz (BIA_{100}). TBW was calculated by using the prediction formula of Lukaski et al (4), ECW by using the prediction formula of Segal et al (16), and intracellular water (ICW) as the difference between the latter 2 quantities. The patients were submitted to BIA measurement before the hypertensive treatment was given. In our department, the first-line treatment is a calcium antagonist (20–40 mg nifedipine).

Outcome measure

Patients were considered to have pregnancy-induced hypertension, without proteinuria, if 2 consecutive, traditional sphygmomanometric measurements of diastolic blood pressure were ≥90 mm Hg after the 20th week of pregnancy (17). Patients were considered to have preeclampsia if 2 consecutive measurements of diastolic blood pressure were ≥90 mm Hg and if urinary protein was ≥300 mg/d, both after the 20th wk of pregnancy (17). No patients with significant edema were enrolled. Two of the 13 patients with hypertension had significant proteinuria (>300 mg/d). No patients had proteinuria only.

Statistical analysis

Descriptive analyses ($\overline{x} \pm$ SD) were conducted for all measured indexes. Two-factor repeated-measures analysis of variance and Tukey's test of significance were performed to evaluate

FIGURE 1. Mean (±SD) bioelectrical impedance analysis (BIA) indexes at 5, 50, and 100 kHz in the women with a normal pregnancy (control group; ■) and in those with gestational hypertension (□). [1]Significantly different from the control group in the same trimester, $P < 0.001$. *Significantly different from the first trimester, $P < 0.02$. °Significantly different from the second trimester, $P < 0.02$.

TABLE 2
Total body water (TBW), extracellular water (ECW), and intracellular water (ICW) in the women with a normal pregnancy (control group) and in those with gestational hypertension[1]

Pregnancy trimester	TBW		ECW		ICW	
	Control group (n = 50)	Hypertensive group (n = 13)	Control group (n = 50)	Hypertensive group (n = 13)	Control group (n = 50)	Hypertensive group (n = 13)
First	36.7 ± 4.4	37.4 ± 16.9	11.0 ± 1.3	11.2 ± 5.0	25.7 ± 3.1	26.4 ± 11.8
Second	40.2 ± 5.0[2]	21.3 ± 14.4[2,3]	12.0 ± 1.5[2]	6.3 ± 4.3[2,3]	28.2 ± 3.5[2]	14.9 ± 10.1[2,3]
Third	44.4 ± 7.2[2,4]	17.5 ± 3.4[2–4]	13.3 ± 2.1[2,4]	5.2 ± 1.0[2,3]	31.1 ± 5.0[2,4]	12.3 ± 2.4[2,3]

[1] $\bar{x}$ ± SD.
[2] Significantly different from the first trimester, $P < 0.05$ (two-factor repeated-measures ANOVA and Tukey's test).
[3] Significantly different from the control group, $P < 0.001$ (two-factor repeated-measures ANOVA).
[4] Significantly different from the second trimester, $P < 0.05$ (two-factor repeated-measures ANOVA and Tukey's test).

differences in MF-BIA and in the calculated body water compartments. Statistical analysis was performed by using SPSS (1988; SPSS, Inc, Chicago).

RESULTS

Of the 173 pregnant women, 57 were excluded from the analysis because they showed signs of chronic hypertension or other pathology (ie, hypertension before the 20th week of gestation, gestational diabetes, abnormal oral-glucose-tolerance-test result, or intrauterine growth retardation), 53 were excluded because they had not completed 3 required measurements for different reasons, 50 had normal pregnancies, and 13 had gestational hypertension. We excluded 13 women because they were taking drugs, corticosteroids, or low-dose aspirin. Additionally, 7 women who had vaginal bleeding during the first ($n = 4$), second ($n = 2$), and third ($n = 1$) trimesters were excluded. Patients with gestational hypertension, preeclampsia, or both during pregnancy were classified as the hypertensive group ($n = 13$) and patients with a normal pregnancy ($n = 50$) were classified as the control group in the longitudinal study. Descriptive analyses of data obtained from the control and hypertensive groups are shown in **Table 1**.

BIA indexes at BIA_5, BIA_{50}, and BIA_{100} are shown in **Figure 1**. The BIA indexes showed an increasing trend in the control group and a decreasing trend in the hypertensive group. In fact, BIA_5 increased significantly between the first and third trimesters and between the second and third trimesters. BIA_{50} and BIA_{100} increased significantly, similar to BIA_5.

Two-factor repeated-measures analysis of variance showed that TBW, ECW, and ICW were not significantly different between the hypertensive and control groups in the first trimester but were significantly different between the 2 groups in the second and third trimesters. TBW, ECW, and ICW increased significantly and progressively throughout pregnancy in the control group and were significantly different between the first and second and third trimesters and between the second and third trimesters. On the contrary, TBW, ECW, and ICW decreased significantly and progressively in the hypertensive group throughout pregnancy and were significantly different between the first and second and third trimesters and between the second and third trimesters (**Table 2** and **Figure 2**).

On the basis of regression analysis, the BIA index was the variable that best predicted longitudinal variations in TBW, accounting for 98% of the value obtained in the first trimester, for 99% in the
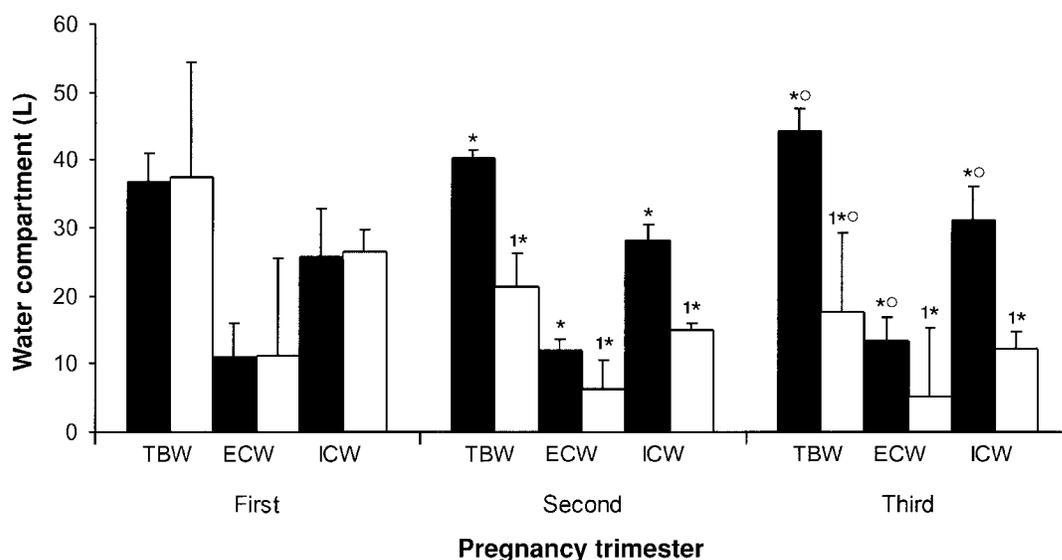
FIGURE 2. Mean (±SD) total body water (TBW), extracellular water (ECW), and intracellular water (ICW) in the women with a normal pregnancy (control group; ■) and in those with gestational hypertension (□). [1]Significantly different from the control group in the same trimester, $P < 0.001$. [*]Significantly different from the first trimester, $P < 0.05$. [°]Significantly different from the second trimester, $P < 0.05$.

second trimester, and for 99% in the third trimester. The BIA index was significantly lower in the hypertensive group than in the control group in the second and third trimesters, suggesting a lack of plasma volume expansion through fluid-retention mechanisms in the hypertensive group (Figure 1). There were no significant differences in hematocrit between the 3 trimesters (data not shown).

DISCUSSION

In pregnancy, the capacity of the vascular bed increases; furthermore, blood volume increases to fill the increased vascular bed. As a consequence, cardiac output must increase. At the same time, the placental implantation process is responsible for the presence of a low-resistance shunt (the placenta), with a subsequent overall effect of a decrease in blood pressure. Hemodynamic changes seem to play a central role in maternal adaptation to pregnancy. Fluid retention is very important in increasing plasma volume, which, in turn, is fundamental in cardiac output increase.

Under normal conditions, TBW and plasma volume are strictly interrelated (18); in turn, plasma volume correlates with birth weight in both humans and animals (19). A defect in plasma volume expansion in pregnancy has been associated with poor pregnancy outcome and low birth weight (19, 20) and, after a subclinical period, preeclampsia. Therefore, an evaluation of variations in TBW in each of the 3 trimesters of pregnancy can provide important data about the maternal physiologic adaptation to pregnancy. The examinations must begin in the first trimester, when some pathologic events (preeclampsia and intrauterine growth retardation) are not established.

It is well known that, during a normal pregnancy, there is progressive fluid retention with a subsequent increase in TBW (21) and in plasma volume. Our results showed that MF-BIA detected variations in body-fluid compartments in the normal-pregnancy group and detected differences in body-fluid compartments between the 2 groups. The significant differences in BIA_5, BIA_{50}, and BIA_{100} between the 2 groups of pregnant women during the 3 trimesters accounted for the known increase in body-fluid volume in the control group. TBW, evaluated by MF-BIA, increased significantly during the 3 trimesters in the control group but not in the hypertensive group, in whom there was a decrease in TBW, strongly suggesting a hemodynamic maladaptation to pregnancy.

A reduction in circulating plasma volume is one indicator of a maladaptation to pregnancy in women who develop gestational hypertension. The mechanism for this relates to the balance between the increase in vascular diameter and endothelial damage that might occur in the absence of fluid redistribution and contribute to the development of gestational hypertension (22). BIA is an easy and painless technique associated with high patient compliance. Our results indicate that MF-BIA is a good monitoring method of longitudinal changes in body fluid compartments in pregnant women and, therefore, a good predictor of normal and abnormal adaptations throughout pregnancy, even in the early stages. Hematocrit did not change significantly during pregnancy and hence it cannot be considered a good predictor of hemodynamic adaptations in pregnancy.

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