Potential use of Bioelectrical Impedance Analysis in the assessment of edema in pregnancy

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Summary

Objective: To evaluate the validity of Bioelectrical Impedance Analysis (BIA) in the assessment of edema in pregnancy.
Methods: A prospective study of healthy women identified during the first trimester of pregnancy. From a pool of 200 eligible volunteers, BIA was conducted on 90 women during the rest of pregnancy and postpartum period.
Results: The values for bioelectrial impedance in normal pregnant women decreased gradually in the course of pregnancy, whereas a more remarkable decrease in the values was noted in eight patients who developed edema. The bioelectrical impedance (BI) changes correlated closely with body weight changes. There was a strong relation between bioelectrical impedance values and the degree of edema. The precedent decrease of the values before the onset of edema was noted in seven of the eight patients with edema.
Conclusion: BIA can be a useful and practical method for the early detection and quantitative assessment of edema in pregnant women.

Key words: Pregnancy; Edema; Bioelectrical impedance analysis.

Introduction

Not only does body fat generally increase during pregnancy, but the amount of total body water also increases with advancing gestation. The fetus, placenta, possibly the amniotic fluid, and maternal blood volume all contribute to the increase in total body water, which represents the largest portion of the body weight gain during pregnancy [1, 2]. Although abnormally increased water retention is usually diagnosed by both edema of the legs and the weight gain, these methods are not quantitative or reproducible.

The purpose of the present study was to quantify the degree of edema using bioelectrical impedance analysis (BIA), which is a widely used method for estimating body composition [3-6], in a series of healthy women and women who developed edema during pregnancy and in the postpartum period. Based on these analyses, it is suggested that the serial measurement of bioelectrical impedance (BI) values can be a reliable method of assessing the degree of edema and it enables earlier detection of edema in pregnancy.

Materials and Methods

Two hundred women, 112 primigravidas and 88 multigravidas, aged 18-36 years (24.1±5.1), body mass index (18-24), were recruited in a consecutive manner between April 1996 and October 1996 during the first trimester of pregnancy (9.9±1.1 weeks) from the antenatal clinic at Kobe University Hospital. Women were eligible for the study if they were free of medical illnesses requiring regular medication and not a regular user of drugs. After being fully informed about the objectives of the study and procedures involved, each woman gave written informed consent. All women had singleton pregnancies and were studied principally every four weeks in the first trimester, every two weeks in the second trimester, every week in the third trimester, at two days after the delivery and finally at four weeks postpartum. Clinical diagnosis of edema was made if the finger pad left an indentation in the tissue when the examiner pressed on the patient's pretibial area for 15 seconds. The degree of edema was assessed as follows: minimal edema of lower extremities; +, marked edema of lower extremities; ++, edema of lower extremities, face and hands; +++.

Determination of BI was made at each antenatal visit with a tetrapolar impedance plethysmograph (TBF-105, Tanita Corp., Tokyo, Japan). The excitation current introduced into the subjects was 800 μ A, AC at 50 kHz. This analyzer enables simultaneous measurements of body weight and impedance in a subject standing on the stainless steel electrodes. To standardize the environmental conditions, all the patients were undressed, and body wieght and BI were measured with bare feet around 10 a.m. after an overnight fast at each visit, as described elsewhere [7, 8].

Data are expressed as mean±S.D. An analysis of variance for repeated measures was performed to evaluate the changes in body weight and bioelectrical impedance during the study. Scheffe's test was used to analyze the differences between means. Pearson product moment correlations were calculated between impedance changes and body weight changes. A statistically significant difference was considered to be $p<0.05$.

Results

In all, 200 eligible women were recruited for the study. Of these, 110 were excluded for failure to complete the evaluation by not coming to our scheduled visits, deve-

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loping medical conditions, or moving from the area. Eighty-two of 90 women enrolled, 45 primigravidas and 37 multigravidas, aged 20-35 years (25.8±4.1), had normal full-term pregnancies and delivered healthy infants without complications during pregnancy and postpartum. The remaining eight women developed clinical edema during the third trimester of pregnancy. A summary of the clinical edema cases is provided in Table 1. All cases developed edema in the third trimester. Cases 4 and 7 had cesarean section due to fetal distress. Case 6 underwent induction of delivery due to the premature rupture of the membranes. All the women who developed edema were treated only with diet and rest.

Longitudinal changes of BI during pregnancy in normal pregnant women without edema are shown in Table 2. The values for BI in normal pregnant women decreased gradually but significantly ($p<0.05$) toward late pregnancy compared to those in early pregnancy. The BI values measured at four weeks postpartum restored to the levels of early pregnancy. There were no significant differences between the BI values measured in late pregnancy and those measured two days after the delivery.

Figure 1 represents the relationship between body weight changes and BI changes of the 90 pregnant women enrolled in the third trimester, where we measured BI values every week. The changes in BI correlated closely with those in body weight ($r= -0.721$, $p<0.001$).

Figure 2 shows serial determination of the BI values throughout pregnancy in the eight women who developed edema in the third trimester. The BI values in the eight women during the third trimester were apparently lower relative to those in pregnant women without edema. Moreover, a substantial decrease in the BI values was noted to procede the development of clinical edema except case 8, in which edema and the decrease of the BI values occurred simultaneously.

The comparison of the mean values of BI in the course of pregnancy in pregnant women without and with edema is represented in Figure 3. The mean values of BI in the eight women with edema were significantly lower in the third trimester versus the values of the women without edema at the same gestational week ($p<0.001$).

Figure 4 shows the relationship between the degree of edema and BI values in the 90 women during the third trimester. As edema worsened, BI values decreased significantly.

Discussion

BIA is a widely used method for estimating body composition that is relatively simple, quick and nonivasive. This method relies on the conduction of a single-frequency, constant electrical current to determine total conductor volume of the body [9]. Because water and electrolytes are both dominant factors affecting electrical conduction in the body, total body water is easily assessed by BIA [10]. It has been shown that human pregnancy is associated with an increase in blood volume and a disproportionate increase in plasma volume relative to red cell mass [11].

The suddenness of excessive weight gain is characteristic of edema rather than physiological weight gain throu-

Table 1. — *Clinical characteristics of pregnant women with edema*

Case No.	Age (yrs)	Gravidity and Parity	Edema	Blood Pressure (mmHg)	Proteinuria (mg/dl)	Outcome
1	30	G3P1	++	125~145/65~80	65	VD at 38w
2	29	G2P0	+	110~120/60~70	–	VD at 38w
3	37	G5P3	+	125~150/70~95	200	VD at 39w
4	34	G3P2	+++	130~190/70~110	65	CS at 35w
5	35	G3P2	+	100~110/55~70	65	VD at 38w
6	26	G2P0	++	120~150/70~95	200	VD at 36w
7	32	G2P1	+++	125~145/60~70	65	CS at 35w
8	36	G1P0	+	105~120/60~75	–	VD at 39w

CS: cesarean section; VD: vaginal delivery.

Table 2. — *Longitudinal changes of BI during pregnancy in normal pregnant women*

Month	3	4	5	6	7	8	9	10	Postpartum	
Gestational week										
mean	9.9	13.2	17.3	21.3	25.5	29.5	33.3	37.3		
±	±	±	±	±	±	±	±	±	2 days	4 weeks
S.D.	1.1	1.3	1.2	1.2	1.1	1.1	1.2	1.2		
Impedance (ohm)										
mean	588.5	560.1	546.0	542.1	544.9	532.2*	527.0*	496.7*	502.4	566.1
±	±	±	±	±	±	±	±	±	±	±
S.D.	83.8	68.3	65.4	77.6	56.8	68.4	59.5	64.9	62.1	55.4

Data are represented as mean ± S.D.
* p<0.05 vs BI value at 3 months

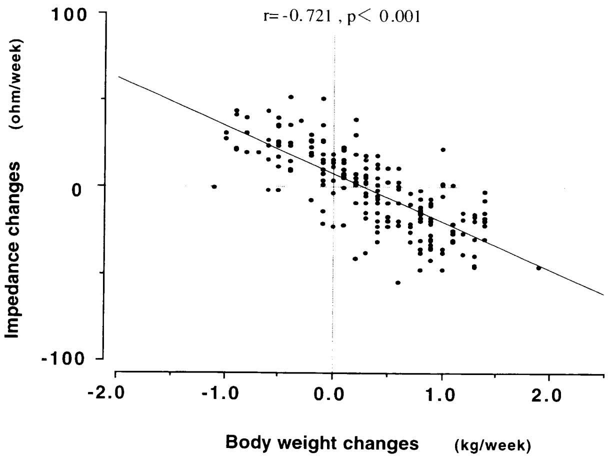

Figure 1. — Relationship between body weight changes and BI changes in the third trimester in 90 pregnant women.

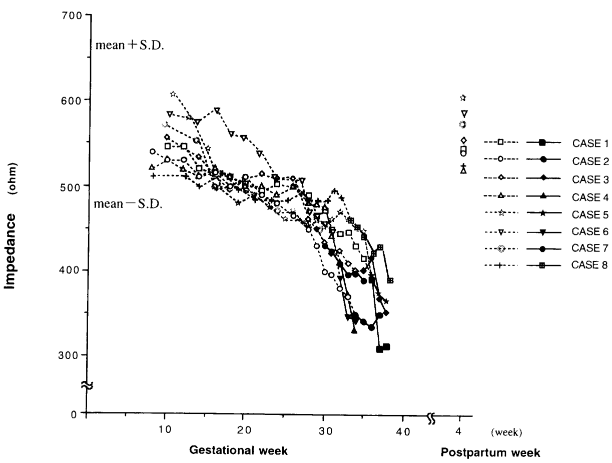

Figure 2. — Serial determination of the BI values throughout pregnancy in eight women who developed clinical edema in the third trimester of pregnancy. Dotted lines and open plots represent BI values before the onset of edema. Solid lines and closed plots represent BI values after the onset of edema. Shaded area represents the mean BI values ± S.D. of normal pregnant women without edema.

ghout gestation. Such a weight gain is due almost entirely to abnormal fluid retention and is usually demonstrable before visible signs of nondependent edema. Because plasma volume expansion directly influences extracellular water, and thus total body water, it is reasonable to suggest that the degree of edema can be quantified with the changes of the bioelectrical impedance to constant electrical current.

The BI values in normal pregnant women decreased gradually throughout pregnancy in the present study, suggesting a physiological increase in total body water. This is in accordance with the report of Lukaski *et al.* [4], who demonstrated that a significant increase in total body water during pregnancy in humans may be accurately assessed with tetrapolar BIA. Theoretically, whole-body BI should be the sum of the BI of the upper limbs, trunk and lower limbs as they are connected in series. Since the BI is inversely proportional to the cross-sectional area, the extremities (which have the smallest cross-sectional area) will have the most influence on BI measurements. The fluid accumulated in the peritoneal cavity contributes little to the whole body BI because it is in one portion of the trunk (a good conductor) and located at the central portion of the abdomen (little current flow) [12].

We found no significant differences between the BI values before the delivery and those after the delivery. It is therefore suggested that, in the BIA employing bipedal electrodes, the changes of BI values directly reflect those of maternal water volume, especially changes in the water volume of the lower limbs.

In the present study, a negative correlation between the changes of BI values and body weight changes during the third trimester was noted, suggesting that water retention is related to weight gain in this trimester. We examined

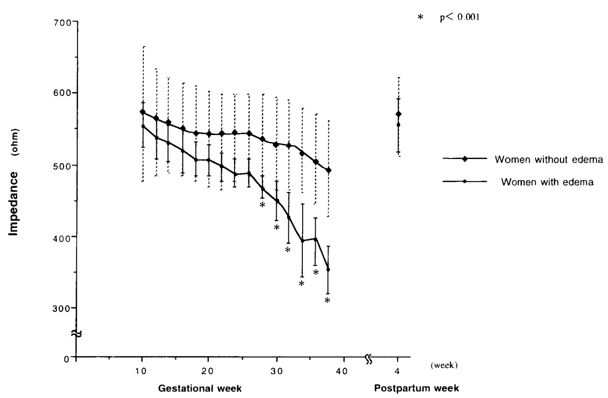

Figure 3. — Comparison of the mean values of BI in pregnant women without and with edema in the course of pregnancy. *p<0.001 versus the values of women without edema at the same gestational week.

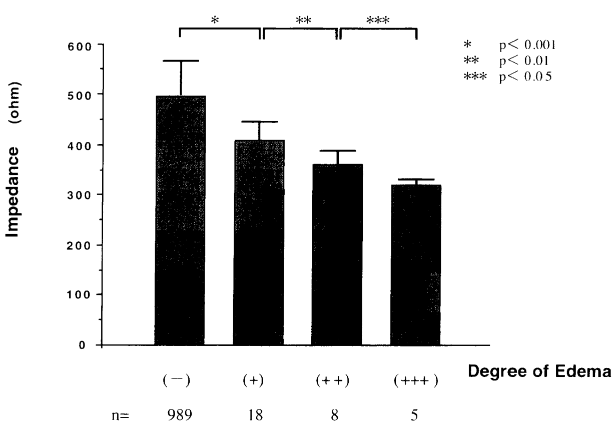

Figure 4. — Relationship between the degree of edema and BI values in the third trimester in 90 pregnant women. *p<0.001, **p<0.01, ***p<0.05.

the validity of the serial measurements of BI values in assessing the degree of edema in pregnancy. In women who developed edema in the third trimester, substantial decreases in BI values were noted relative to those in normal pregnant women without edema and the values markedly decreased as edema declined. Moreover, in these women with edema the decrease in the BI values preceded the onset of edema except one case in which edema and the decrease of the BI values occurred simultaneously. These results suggest that the serial measurement of BI values is a more reliable method of assessing the degree of edema than diagnosis by pressing on the patient's pretibial area, and enables earlier detection of abnormal water retention which leads to edema in the third trimester. In addition, a close relationship between the BI values and degree of edema was observed in the third trimester. These findings indicate that BI values can be considered as a valuable index to quantify the changes of body water retention and the degree of edema.

The speed and simplicity of this noninvasive technique, which does not require active participation by the patient, and the information gained is the asset of BIA. Although etiology of edema in pregnancy involves consideration of many factors, the potential of BIA in the assessment and prediction of edema seems ensured.

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References

[1] Hytten F. E.: "Weight gain in pregnancy". In: "Clinical physiology in obstetrics". Hytten F., Chamberlain G. (eds.), Oxford, Blackwell Scientific Publishers, 1980, 193.

[2] National Academy of Science: "Nutrition during pregnancy". Washington DC: National Academy Press, 1990, 121.

[3] Segal K. R., Gutin B., Presta E., Wang J., Van Itallie T. B.: "Estimation of human body composition by electrical impedance methods: a comparative study". *J. Appl. Physiol.*, 1985, *58*, 1565.

[4] Lukaski H. C., Blonchuk W. W., Hall C. B., Siders W. A.: "Validation of tetrapolar bioelectrical impedance method to assess human body composition". *J. Appl. Physiol.*, 1986, *60*, 1327.

[5] Lukaski H. C., Johnson P. E., Bolonchuk W. W., Lynkken G. I.: "Assessment of fat-free mass using bioelectrical impedance measurements of the human body". *Am. J. Clin. Nutr.*, 1985, *41*, 810.

[6] American Society of Clinical Nutrition: "Bioelectrical impedance analysis in body composition measurement: National Institutes of Health Technology Assessment Conference Statement". *Am. J. Clin. Nutr.*, 1996, *64 (Suppl.)*, 524S.

[7] Hainer V., Kunesova M., Parizkova J., Stich V., Horejs J., Muller L.: "Body fat assessment by a new bipedal bioimpedance instrument in normal weight and obese women". *Sb. Lek.*, 1995, *96*, 249.

[8] Kushner R. F., Gudivaka R., Schoeller D. A.: "Clinical characteristics influencing bioelectrical impedance analysis measurements". *Am. J. Clin. Nutr.*, 1996, *64 (suppl.)*, 423s.

[9] Nyboer J.: "Workable volume and flow concepts of bio-segments by electrical impedance plethysmography". *Life Sci*, 1972, *2*, 1.

[10] Hoffer E. C., Meador C. K., Simpson D. C.: "Correlation of whole-body impedance with total body water volume". *J. Appl. Physiol.*, 1969, *27*, 531.

[11] Hytten F.: "Blood volume changes in normal pregnancy". *Clin. Haematol.*, 1985, *14*, 601.

[12] Chumlea W. C., Baugmartner R. N., Roche A. F.: "Specific resistivity used to estimate fat-free mass from segmental body measures of bioelectric impedance". *Am. J. Clin. Nutr.*, 1988, *48*, 7.

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