Total body water estimation and maternal cardiac systolic function assessment in normal and gestational hypertensive pregnant women

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Source of support: none.

Summary

Background: The importance of establishing correlations between cardiac function (cardiac output and stroke volume) and total body water (TBW) content in normal and hypertensive pregnancy focuses primarily on their potential relevance in treatment. Total body water content and cardiac function were evaluated in 25 normotensive (N) and 22 gestational hypertensive (GH) pregnant women matched for age, gestational age, and pre-pregnancy body mass index (BMI) during the third trimester of gestation.

Material/Methods: Patients underwent maternal echocardiography, bioelectrical impedance analysis (BIA), and hematocrit (Hct) evaluation, and the water balance index (WBI), i.e. the ratio of total body water to hematocrit, was computed. Hematocrit showed significantly lower values in normal than in GH women (31.9±2.2% vs. 36.2±2.5%; p<0.001).

Results: There was no difference in TBW between the two groups. The WBI was higher in normal than in GH women (1.35±0.20 l.kg⁻¹.m⁻² vs. 1.19±0.18 l.kg⁻¹.m⁻²; p<0.001). Normal subjects showed a higher stroke volume than GH patients (78.0±9.7 ml vs 67.9±10.2 ml; p=0.001). Atrial function was also higher in normal than in GH women (left atrial fractional area change: 57.4±5.1% vs. 42.5±7.5%; p<0.001). Correlation was found between stroke volume and WBI (r=0.93, p<0.0001).

Conclusions: Maternal cardiac function and the water balance index are strongly related and might help in comprehending the mechanisms of adaptation in physiologic and hypertensive pregnancy.

key words: pregnancy • cardiac function • bioelectrical impedance analysis • total body water • hematocrit


Word count: XXX
Tables: 5
Figures: 2
References: 26

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BACKGROUND

Recently, the modifications in maternal cardiac function have been assessed during normotensive pregnancy [1–5] and pregnancy-induced hypertension [6–8]. In normal pregnancy, cardiac output increases and diastolic function is modified, consisting of a rise in preload, a decreased afterload, an increased compliance of the conduit vessels, ventricular remodeling, and a modification of the renin-angiotensin-aldosterone system [5,9]. Cardiac output is increased as a result of enhanced myocardial performance [10]. Left atrial dimensions increase gradually from early pregnancy, reaching a plateau at 30 weeks of gestation [1,3,11], and appear to result from the increase in preload and circulating blood volume. The modifications of cardiac performance are said to be due to hemodilution and the increase in preload [1,3,5].

In complicated pregnancies, stroke volume and cardiac output appear to be lower and the left atrial function is depressed [7,8]. It has been hypothesized that an inadequate plasma volume expansion might be one of the causes of cardiac dysfunction in hypertensive disorders in pregnancy and fetal growth restriction [12,13]. This hypothesis is mainly derived from indirect information regarding cardiac chamber size changes during pregnancy [1,3,5,11].

Estimation of total body water (TBW) can now be easily achieved using bioelectrical impedance analysis (BIA). This method relies on the conductance of an alternating electric current to determine the total conductor volume of the body [14,15]. Because water and electrolytes are the main factors affecting electrical conductance, TBW is easily assessed by BIA [16,17]. Previous reports have validated this approach to estimate TBW in adults, children, and in pregnancy [15,17–19], and a recent paper by Bolanowski [20] asserted the suitability of bioimpedance analysis for the assessment of body components in normal adults in place of traditional dual-energy x-ray absorptiometry (DEXA).

For this reason, an integrated analysis of TBW and maternal echocardiographic data of left atrial and ventricular function might be useful in comprehending the relationship between plasma volume expansion and cardiac function. To this aim we assessed total body water content and cardiac function in a group of normotensive subjects (N) and a group of gestational hypertensive patients (GH) during the third trimester of gestation.

MATERIAL AND METHODS

Twenty-five normotensive pregnant women (N) and twenty-two consecutive non-proteinuric, gestational hypertensive patients (GH) matched for age, gestational age, and pre-pregnancy body mass index (BMI) were enrolled in the study during the third trimester of gestation. Gestational hypertension was diagnosed according to the definition of Davey and MacGillivray [21]: diastolic blood pressure >90 mmHg in two measurements 4 hours apart. None of these women had received medications other than iron supplements and vitamins prior to their enrollment in the study. Approval of the University Ethics Committee was obtained and written informed consent was collected from all patients.

Echocardiographic evaluation

M-mode, 2-D, and Doppler echocardiographic evaluations were performed with the patient in the left lateral position using a commercially available echocardiograph (Acuson Sequoia; Hewlett Packard Sonos 2500), and recorded on super VHS videotape. All data were recorded with patients in this position during end-expiration apnea. The main cardiac parameters evaluated are reported in Table 1.

Table 1. Main cardiac parameters evaluated in the study.

<table>
<thead>
<tr>
<th>Parameter</th>
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<tbody>
<tr>
<td>Atrial dimensions and function</td>
<td>Left atrial maximum and minimum area (cm²)</td>
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<td></td>
<td>Left atrial fractional area change (%)</td>
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<td>Left ventricular morphology</td>
<td>End-systolic and diastolic volume (ml)</td>
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<td>Left ventricular function</td>
<td>Stroke volume (ml)</td>
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<td></td>
<td>Cardiac output (ml)</td>
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<td>Ejection fraction (%)</td>
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M-mode and 2-D echocardiography

Left atrial and aortic route diameters, left ventricular end-diastolic and end-systolic diameters (LVDD and LVDs, respectively), and interventricular septum and posterior wall diastolic thickness (IVSD and PWd, respectively) were all detected in the parasternal long axis view during M-mode tracing according to the recommendation of the American Society of Echocardiography [22]. Left ventricular end-diastolic and end-systolic volumes (EDV and ESV, respectively) were calculated according to Teicholz [23]. Stroke volume (Str. Vol.) was calculated as the difference between EDV and ESV. Cardiac output (CO) was obtained as the product of stroke volume and heart rate (HR) derived from the electrocardiographic monitoring.

The ejection fraction (EF%) was calculated as the ratio of the stroke volume to the volume of blood remaining in the left ventricle after diastole. Measurement of the ejection fraction is used clinically to determine myocardial contractility, which represents the performance of the heart. Left atrial dimension and function were detected as previously described [5,7,8] considering left atrial minimum area (LA min) and left atrial maximum area (LA Max); the assessment of left atrial function was obtained through left atrial fractional area change (LA FAC).

Anthropometry and BIA determination

BIA measurements were performed on each subject after a period of rest (1–2 hours). Standing height was measured with a stadiometer. Body weight was determined...
with the Tefal calibrated scale (Tefal, Rowenta), the same used for BIA determination. Body mass index (BMI) was calculated according to the formula weight/height².

BIA was measured by determining resistance (R, Ω/Ohm) and reactance (Xc, Ω/Ohm) with the Tefal scale (Tefal, Rowenta). The device has a tetrapolar impedance plethysmograph with 4 aluminium foil electrodes (Tefal, Rowenta). The device has a tetrapolar impedance plethysmograph with 4 aluminium foil electrodes placed at the metatarsophalangeal joints of each foot on one electrode. An alternating excitation current of 800 µA was then introduced at the calcaneal electrode and the voltage drop across the patient was detected with the metatarsal electrodes. The bioelectrical impedance was measured at 50 kHz (BIA50). The variability of repeated R and Xc measurements determined on the same day was less than 1 Ω. The multiple-regression equation of Lukaski [24] was used to estimate total body water (TBW) (in liters).

Hematocrit (Hct) was determined along with the routine blood specimen, collected within 48 hours.

Statistical analysis

Data were expressed as means±SD. Comparison between the normotensive and gestational hypertensive women was performed using the Student’s t-test for unpaired data. Linear regression analysis was performed by the least squares method. Intra- and interobserver variability for the echocardiographic variables were tested in previous reports [5,7,8].

Results

The clinical features of the two groups are shown in Table 2. Hematocrit (Table 3) results were significantly lower in the N group than in the GH group (31.9±2.2% vs. 36.2±2.5%; p<0.001). There was no difference in TBW (Table 3) between normotensive and gestational hypertensive patients (42.8±5.1 l vs. 42.8±5.8 l; p=NS). The ratio TBW/Hematocrit was higher in normotensive than in gestational hypertensive women (1.35±0.20 l/kg/m² vs. 1.19±0.18 l/kg/m²; p<0.001) (Table 3).

Echocardiographic parameters are shown in Table 4. End systolic volume was lower in the N group than the GH group (28.7±7.0 ml vs. 39.6±10.4 ml; p<0.001), whereas no difference was found in end diastolic volume (106.8±13.9 ml vs. 107.5±17.5 ml; p=NS) between the two groups. There was evidence of a higher stroke volume in normotensive patients with respect to gestational hypertensive patients (78.0±9.7 ml vs. 67.9±10.2 ml; p=0.001), whereas there was a slight, insignificant difference in CO between the two groups (6.57±1.02 ml vs. 5.78±1.69 ml; p=0.051). The ejection fraction was higher in the N group than the GH group (73±4% vs. 63±5%; p=0.001). Left atrial minimal area was significantly lower in normotensive women compared with gestational hypertensive women (6.2±1.0 cm² vs. 8.5±1.48 cm²; p<0.001), whereas there was no difference in left atrial maximal area between the two groups (14.8±1.1 cm² vs. 14.6±1.1 cm²; p=NS). Left atrial fractional area change was higher in normotensive women than in gestational hypertensive women (57.4±5.1% vs. 42.5±7.5%; p<0.001).

Correlations

We calculated Pearson’s coefficients of correlation considering Hct, BMI, TBW and TBW/Hct as independent variables and the cardiac-function parameters, i.e. left atrial fractional area change (LA FAC%), Str. Vol, CO, and EF%, as dependent variables. The results are shown in Table 5.
Table 5. The best correlations were found between Hct and LA FAC (Figure 1) and between TBW/Hct (water balance index) and stroke volume (Figure 2). Figure 2 shows the distribution of stroke volume in relation to the water balance index (WBI), with evidence of an area of absence of overlap between the two groups (bottom left).

**Discussion**

During normal pregnancy, an increase in vascular bed capacity, blood volume, and cardiac output occurs. Plasma volume expansion during normotensive pregnancy is a physiological event that appears to be related to cardiac function enhancement [5,8,11]. Modifications of left atrial and ventricular dimensions and function, already described during normotensive and hypertensive pregnancies, appear to be linked to the hemodilution process [5,7,8], although there is no direct data confirming this hypothesis.

TBW has been reported to be directly related to plasma volume in normal conditions [24]. On the other hand, hematocrit (Hct) has been shown to be elevated in hypertensive pregnancies due to an inadequate plasma volume expansion [26]. Our hypothesis was that both total body water and hematocrit might play an independent role in influencing cardiac performance. BIA and hematocrit evaluation might therefore help in understanding normal and pathological aspects related to plasma volume and their relationship with cardiac performance. In fact, bioimpedance analysis has recently been proposed for use in measuring body compartments, this method having the same properties as the classic densitometric methods, considered the ‘gold standards’ for estimating human body composition [20].

In our results, only the cardiac function parameters, hematocrit, and WBI were different between the N and GH patient groups, whereas we expected a difference in total body water, though it was not possible to find this. The ratio of total body water and hematocrit, which we defined as the Water Balance Index, may provide a measure of the relation existing between the fluid component (plasma volume) and the cellular component of the blood, and might express the preload condition better than TBW or Hct considered separately: a low WBI seems to be linked in our results with a low cardiac systolic function, as shown by the correlation between WBI and stroke volume. The present study provides for the first time direct evidence of the relationship between preload, expressed by the water balance index (WBI), and left heart function during the third trimester of pregnancy. Our data show that WBI is directly and strictly related to cardiac systolic function, whereas the similar values of TBW found in the N and GH patients might be explained by the existence of a wide variety of pathophysiologic conditions typical of gestational hypertension. The correlation existing between left atrial function and Hct, stronger than the correlation between left atrial function and WBI, might be explained by the low pressure present in the left atrium compared with the left ventricle: in fact, a high value of hematocrit may increase blood viscosity, influencing the function of a cardiac chamber working at a low-pressure regimen, such as the left atrium, more than a chamber working at high-pressure values, such as the left ventricle.

The most interesting result, shown in Figure 2, is the existence of a subgroup of gestational hypertensive patients with low WBI and altered cardiac systolic function. This group (bottom left part of Figure 2) might represent the portion of gestational hypertensive patients in whom maternal cardiac maladaptation would be more probable. A longitudinal prospective study is ongoing to verify this hypothesis.

**Conclusions**

The extensive application of the combination of the two methods (maternal echocardiography and BIA evaluation) might increase our understanding of the circulatory adaptation mechanism in hypertensive pregnancy in the future.

**References:**

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