OBSTETRICS

Cardiac magnetic resonance imaging to assess the impact of maternal habitus on cardiac remodeling during pregnancy

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BACKGROUND: It is well known that the maternal cardiovascular system undergoes profound alterations throughout pregnancy. Interest in understanding these changes has led investigators to use evolving and increasingly sophisticated techniques to study these changes, most recently with 2-dimensional echocardiography. Despite its clinical utility, echocardiography has limitations, and cardiac magnetic resonance imaging (CMRI) has become increasingly used for evaluation of cardiac structure and function.

OBJECTIVE: We used CMRI to evaluate cardiac remodeling according to maternal habitus throughout pregnancy and postpartum.

STUDY DESIGN: This was a prospective, observational study of nulliparous women aged 18-30 years, without preexisting medical conditions, conducted from October 2012 through December 2014. Women were classified according to prepregnancy body mass index (BMI) as either normal (BMI 18.5-24.9 kg/m^2) or overweight (BMI 25-35 kg/m^2). All women underwent CMRI during 5 epochs throughout gestation: 12-16 weeks, 26-30 weeks, 32-36 weeks, at delivery, and 3 months' postpartum. Using left ventricular mass (LVM) as a marker of cardiac remodeling, the 2 cohorts were compared.

RESULTS: There were 14 normal-weight (BMI 22.2 $\pm$ 1.3) and 9 overweight (BMI 29.1 $\pm$ 2.0) women who participated in the study. Beginning at 26-30 weeks and continuing to delivery, LVM of both normal-weight and overweight women was significantly increased compared with the respective first-trimester studies for each cohort ($P < .001$). LVM of both cohorts returned to their index values by 3 months' postpartum. The geometric ratio of LVM to left ventricular end-diastolic volume was calculated, and both normal-weight and overweight women demonstrated concentric remodeling throughout gestation, however this resolved by 12 weeks' postpartum.

CONCLUSION: There is substantial cardiac remodeling during pregnancy with significant increases in LVM that are proportional to maternal size. Left ventricular geometric remodeling was concentric in both normal-weight and overweight women. All changes in cardiac remodeling resolved by 3 months' postpartum.

Key words: cardiac magnetic resonance imaging, cardiac remodeling, concentric hypertrophy, left ventricular mass

Introduction

It is well known that the maternal cardiovascular system undergoes profound alterations throughout pregnancy, including increased cardiac output, heart rate, and plasma volume expansion.[1,2] Interest in understanding these changes has led investigators to use evolving and increasingly sophisticated techniques to study these changes, initially with dye-dilution techniques, then invasive right-heart catheterization, to now noninvasive techniques of cardiovascular assessment with 2-dimensional (2D) echocardiography.[3,4,6] With this latter technology it was shown that in response to these physiologic changes, cardiac remodeling accrues across pregnancy with increasing cardiac mass.[5-8]

Despite its clinical utility, echocardiography has limitations that include its wide interobserver and intraobserver variability, necessary geometric assumptions, and technical difficulty in evaluating obese subjects.[9-11] Over the past decade, cardiac magnetic resonance imaging (CMRI) has been shown to have superior high-resolution imaging capabilities free from the limitations of 2D echocardiography.[10,12-14] Due to the advantages of superior spatial resolution, CMRI has become the gold standard for assessment of regional and global systolic function, myocardial viability, and evaluation of complex congenital heart disease.[15-17]

To date there have been only a few reports that describe the CMRI in pregnant women. And although 2 recent studies described CMRI findings in healthy pregnant women compared with nonpregnant controls, neither addressed longitudinal changes across pregnancy.[15,16] Because of this, we designed the current study to evaluate changes in cardiac size according to maternal habitus throughout pregnancy and the postpartum period for both normal-weight and overweight women. A second aim of this study was to determine the pattern of geometric remodeling specific to pregnancy.

Materials and Methods

This was a prospective, longitudinal observational pilot study of nulliparous pregnant women from October 2012 through December 2014. Approval was obtained from the institutional review board of the University of Texas Southwestern Medical Center. The study included nulliparous women aged 18-30 years of age with singleton gestations, who had no current or chronic medical disorders—specifically, they had no hypertension, diabetes, or underlying cardiovascular disease. All women were nonsmokers, none used illicit drugs, and all abstained from alcohol during

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pregnancy. These women were enrolled after giving informed consent at entry into prenatal care into the practices of full-time faculty members of University of Texas Southwestern Medical Center, St Paul University Hospital. Their entry was stratified into 1 of 2 groups based on prepregnancy body mass index (BMI): normal-weight women with a BMI of 18.5-24.9 kg/m^2 and overweight women with a BMI of 25-35 kg/m^2.

Each woman underwent 5 CMRI studies throughout pregnancy and postpartum at prespecified epochs: 12-16 weeks, 26-30 weeks, 32-36 weeks, within 48 hours of delivery, and 12 weeks' postpartum. A nominal compensation was provided to offset incurred expenses. CMRI scans were performed on 1 of 2 comparable 1.5-T coil systems (Intera 1.5T and Ingenia 1.5T; Philips Medical Systems, the Netherlands). No sedatives or contrast agents were used, and all studies were initially performed in the left lateral tilt position and repeated in the supine position after a 5- 10-minute normalization period. CMRI mass and volumes were analyzed from short-axis, breath-hold, prospectively electrocardiographic-gated steady-state free precession sequence magnetic resonance images obtained from a 1.5-T magnetic resonance imaging system (Philips Medical Systems). We obtained 8-mm slices with a 0-mm gap between slices from the base through the apex of the heart on all subjects, temporal resolution 40 ms. Endocardial and epicardial borders were traced manually offline using software (Medis Qmass 6.2.3; Medis, Leiden, The Netherlands) by a level II CMRI cardiologist with 6 years of experience to measure LV cavity and wall volume in each slice at end-diastole and end-systole. Measurements from each slice were summed using the method of disks. Myocardial mass was estimated by multiplying the myocardial wall volume at end-diastole by the specific gravity of muscle (1.05 g/mL). The papillary muscles were not included in the myocardial mass. Wall thickness was measured as 60 radial chords in each slice as the distance from the epicardial to endocardial border and then averaged >6 segments in each slice to obtain an average thickness in the anterior wall, anterolateral wall, inferolateral wall, inferior wall, inferoseptum, and anteroseptum, respectively. The most proximal and distal slices were excluded from the determination of the average thickness.

For this analysis, left ventricular mass (LVM) was determined longitudinally at each epoch with each woman serving as her own control. Given the possible implications of maternal weight gain during pregnancy, LVM was then indexed to maternal height. To further analyze the left ventricular dimensional changes during pregnancy and the postpartum period, the average thickness of all left ventricular wall segments within each CMRI slice was calculated as described above. Lastly, patterns of cardiac remodeling vis-à-vis ventricular eccentric vs concentric changes[18] were calculated using the geometric ratio of LVM to left ventricular end-diastolic volume (LVEDV). In brief, members of our research team have previously characterized left ventricular hypertrophy—ie, remodeling—based on left ventricular geometry.[19] Concentric remodeling was defined as an increase in the relative cardiac mass greater than that of cardiac volume with a resultant increase in the ratio of LVM to LVEDV.[18,19] Eccentric remodeling was defined as an increase in relative cardiac mass with a proportionally greater increase in chamber volume size, with a resultant decrease in the LVM/LVEDV. Considering the unpredictable volume fluctuations following delivery and its effect on subsequent volume measurements, measurements taken in the immediate postpartum CMRI (epoch 4) were excluded for concentricity and wall thickness analysis.

Variables were compared as a function of time stratified by maternal BMI in each epoch. The results were then compared following adjustment for maternal weight in both cohorts to correct for pregnancy-related weight gain. A continuous estimation of LVM was then performed, using a mixed random and fixed effects model. Gestational age was entered as a quadratic expression using the weeks' gestation at the measurement as the random effect, obesity classification as the fixed effects with an interaction between obesity classification and the observed weeks' gestation, with an unstructured covariance pattern estimated. P values $<$ .05 were considered significant. Significant P values reported are not adjusted for multiple comparisons. Statistical analysis was completed using software (SAS 9.3; SAS Institute Inc, Cary, NC).

Results

During the 2-year study period 23 women were enrolled and each underwent 5 CMRI studies; no women dropped out of the study. One obese black woman was delivered at 34 weeks for severe preeclampsia and her data were excluded from this analysis. The mean maternal age was 27 $\pm$ 2.8 years. Within the entire cohort, 14 (61%) women were white, 6 (26%) were black, and 3 (13%) were Hispanic. There were 14 normal-weight women, with a mean BMI of 22.2 $\pm$ 1.3 kg/m^2, and 9 overweight women with a mean BMI of 29.1 $\pm$ 2.0 kg/m^2. Of the 14 normal-weight women, 12 (86%) were white, 1 (7%) was black, 1 (7%) was Hispanic. The overweight cohort included 2 (22%) white, 5 (55%) black, and 2 (22%) Hispanic women. Shown in Table 1 are data for maternal habitus and blood pressure across pregnancy. While overweight women were larger, their trend in weight gain was similar to that of normal-weight women. Both groups of women proportionally gained a similar amount of weight beginning at 12-16 weeks and continuing through 32-36 weeks (19% vs 15%, $P = .18$). Overweight women had a significant increase in systolic blood pressure at 26-30 weeks and 32-36 weeks as compared to 12-16 weeks ($P = .03$ and $P = .01$, respectively). They also had a significant increase in mean arterial pressure at 26-30 weeks and 32-36 weeks as compared to 12-16 weeks ($P = .02$ and $P = .01$, respectively). The diastolic blood pressure of overweight women was also increased at 32-36 weeks when compared to enrollment ($P = .04$). There were no significant changes in the blood pressure profile of normal-weight women.

As shown in Figure 1, LVM significantly increased from epoch 1 (12-16