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Assessment of right heart function in preeclampsia by echocardiography

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ABSTRACT

Background: Preeclampsia (PE) is a multisystemic disorder characterized by hypertension and proteinuria that is specific to pregnancy and associated with maternal and fetal morbidity-mortality.
Aim: To assess right heart structure and function in PE by echocardiography using conventional and tissue Doppler techniques.
Methods: In total, 67 women with untreated PE and 46 matched healthy pregnant women were included. PE was defined according to the ACOG (2002) criteria. Right and left heart functions were evaluated using transthoracic two-dimensional (2D) echocardiography with color Doppler and tissue Doppler imaging techniques.
Results: Right ventricular basal and outflow tract diameters and free wall thickness, right atrial end-systolic maximum diameter, and area were significantly higher in the PE group than the control group ($p < 0.05$). Tricuspid annular plane systolic excursion, isovolumic acceleration time, tissue Doppler-derived tricuspid lateral annular systolic velocity (S'), right ventricle fractional area change, and myocardial performance index (Tei) were significantly lower in the PE group than the controls ($p < 0.05$).
Conclusions: PE does not only affect the left side of the heart but also the right side. This finding may open new scenarios, because right ventricular dysfunction may also be responsible for PE-related morbidity.

1. Introduction

Preeclampsia (PE) is a multisystem disorder specific to pregnancy, characterized by maternal hypertension and proteinuria, with cardiovascular complications, and affecting ~5–7% of all pregnancies [1–3]. Although the pathophysiology is not yet fully understood, inadequate placental invagination and related endothelial injury of the uteroplacental and systemic circulation and vasospasm are involved in the fundamental pathophysiology of PE [4]. Abnormal placentation leads to reduced perfusion, hypoxia, free radical formation and increased oxidative stress, which is related to maternal-fetal morbidity-mortality [3,4]. PE is associated with an increased risk of developing cardiovascular disease in later life [5].

Previous echocardiographic studies have reported conflicting results, mainly because they have used different echocardiographic techniques and assessed load-dependent indices in different patient groups [5]. Moreover, most of the studies have focused on functional and structural alterations occurring in the left side of the heart [6]. There is a lack of published data on the myocardial structure and function of the right side of the heart in PE [6]. The aim of our study was to assess right-side heart geometry and myocardial performance in term PE using conventional echocardiography and tissue Doppler techniques.

2. Methods

2.1. Subjects

This was a prospective observational case-control study carried out from May 2011 to October 2013 in our hospital; 66 women with term PE and 46 gestational-age-matched healthy pregnant women at gestational age > 37 weeks were included. Our institutional Ethics Committee approved the trial and written informed consent was obtained from all subjects. PE was defined and classified according to the American College of Obstetricians and Gynecologists (ACOG) (2002) criteria [7]. Term PE was defined as women with PE not requiring delivery before 37 weeks of gestation related to PE worsening. Blood pressure was measured manually

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using a Riester mercury sphygmomanometer according to the guidelines of the National High Blood Pressure Education Program Working Group on High Blood Pressure in pregnancy [9]. All of the measurements were performed in the left arm, in the sitting position, with the arm at the level of the heart. Pre-partum body mass index (BMI) was calculated based on the following formula: Body weight in kilograms divided by height in meters squared.

Subjects with chronic/gestational hypertension, comorbidities, other pregnancy complications, multiple gestations, smokers, and subjects on medication or in active labor, were excluded.

The postpartum study assessment protocol included a physical examination and BP profile. Women with persistent high BP 12 weeks after delivery were subsequently excluded from the study because they presumably had unrevealed preexisting systemic hypertension.

2.2. Echocardiography

Echocardiography was performed in all of the subjects. Transthoracic echocardiography (TTE) recordings were performed while the patients were in the left lateral decubitus position. Apical four-chamber views (A4CW), as well as two-chamber and parasternal images, were recorded at expiratory apnea for three consecutive cardiac cycles using a 1.5–3.6 MHz phased-array transducer with a Vivid 5 (GE Vingmed Ultrasound, Horten, Norway) echocardiography device. Records were analyzed by two physicians, who were blinded to the study. Electrocardiography was recorded continuously during echocardiographic studies. Two-dimensional, M-mode, and tissue Doppler TTE imaging were performed according to American Society of Echocardiography guidelines, as described previously [6,8].

2.3. Left-sided cardiovascular system assessment

M mode measurements of the left ventricle (LV), interventricular septal wall thickness (IVSWT), posterior wall thickness (PW), and LV end-diastolic and end-systolic diameters (LVEDd and LVESd, respectively) were obtained from the left parasternal short axis (PSAX) view while the cursor was perpendicular to the mitral leaflets. LV mass was calculated with the Devereux formula [8]. Left atrium (LA) dimensions were measured at end-systole from the left parasternal longitudinal long axis (PLAX) view. Left atrial maximal area was measured at end-systole from A4CW.

LV systolic functions were evaluated by ejection fraction (EF), cardiac output, stroke volume, and MPI (myocardial performance index; both tissue-Doppler image [TDI] and pulse Doppler image [PDI]). EF was measured by the modified Simpson method. Left ventricular wall motion was analyzed from four different windows after dividing the left ventricle into 16 segments. Stroke volume and cardiac output were calculated from aortic outflow velocities using related formulas, described elsewhere [8]. Systemic vascular resistance (SVR) was calculated using the formula: SVR = [mean arterial pressure/cardiac output) $\times$ 80].

Apical five-chamber images were used to calculate MPI. The PW Doppler trace was placed at the tip of the anterior mitral valve. Images with both high quality mitral filling and aortic ejaculation curves were recorded. Isovolumic contraction time (IVCT) was defined as the period between the end of the mitral *A* wave to the beginning of the systolic aortic ejection (*S*). Isovolumic relaxation time (IVRT) was defined as the time between the end of the *S* wave to the beginning of the diastolic mitral *E* wave. The period between the beginning and end of the *S* wave was described as the ejection time (ET). MPI was calculated from the formula: MPI = (IVRT + IVCT)/ET.

For MPI assessment by TDI, we used apical four- and two-chamber images. The PW sample volume was first placed at the left ventricle septal wall, then at the lateral wall adjacent to the mitral annulus in the apical four-chamber view. Afterwards, PW Doppler measurements were recorded from the anterior and inferior walls adjacent to the mitral annulus from an apical two-chamber view. The electrocardiogram horizontal speed was set to 100 mm/s during the recordings.

The MPI of each segment was calculated separately to determine regional MPI. The E' wave was determined as the early diastolic filling velocity; the A' wave was the late diastolic filling velocity, and the S' wave was the peak systolic velocity. IVCT was defined as the time interval from the end of the A' wave to the beginning of the S' wave; IVCT was the interval between the end of the S' wave to the beginning of the E' wave, and ET was the interval between the beginning and end of the S' wave. MPI was calculated using the same formula given above. Mean tissue Doppler MPI was obtained from the average of the TDI-MPI measurements of the four different segments.

2.4. Diastolic functions

LV diastolic functions were assessed by both PDI and TDI methods. Mitral early diastolic (*E*) and late diastolic (*A*) flow rates, *E*/*A*, deceleration time (DT), and IVRT were measured from A4CW with PDI. Lateral mitral annular velocities were measured from A4CW by TDI and mean values were recorded. Early diastolic mitral velocity (e') was recorded to calculate the E/e' ratio.

2.5. Right-sided cardiovascular system assessment

A4CW, a modified apical four-chamber view (mA4CW), the PLAX, the PSAX, and the left parasternal right ventricular inflow (RV) views were obtained to assess the right heart.

RV basal diameter (RV-Bd) was measured from A4CW, focusing on RV at end-diastole. The right atrium (RA) long and short axis diameters (RAd-lax/RAd-sax) and right atrial area (RAA) were measured from A4CW at end-systole. The right ventricular outflow tract was measured from left PSAX at end-diastole. RV free wall thickness (RV-Wth) was measured from left PLAX at end-diastole using M-mode.

Pulmonary artery systolic pressure was measured with the Bernoulli equation ($P = 4v^2$) from the tricuspid regurgitation jet flow. Estimated systolic pulmonary artery systolic pressure was then calculated by adding 5–20 mmHg, according to inferior vena cava width and inspiratory collapse, to pulmonary artery systolic pressure (PASP), as suggested by the related guidelines [6].

Right ventricle myocardial performance index (RMPI), tricuspid annular plane systolic excursion (TAPSE), isovolumic acceleration (IVA), right ventricle two-dimensional (2D) fractional area change (RV-FAC), and tissue Doppler-derived tricuspid lateral annular systolic velocity (TDI-S') were used to assess right ventricular systolic function. TAPSE is a measure of RV longitudinal function; however, it is well-correlated with global RV systolic function. TAPSE was measured from A4CW, using M-mode tracing crossed from the tricuspid annulus-lateral free wall junction point. TAPSE is usually acquired by placing an M-mode cursor through the tricuspid annulus and measuring the amount of longitudinal motion of the annulus at peak systole. RIMP was obtained by two methods using related formulae: PDI and TDI, because the correlation between the methods is modest and 'normal' values differ on the basis of the method chosen. The MPI is defined as the ratio of isovolumic time divided by ET, or [(IVRT + IVCT)/ET]. For MPI calculation by TDI, sample volume was at the tricuspid lateral annulus for all time intervals, and was calculated using the same formula given above.

IVA and TDI-S' were obtained from A4CW, while the cursor of PW TDI was at the junction point of the RV free wall-tricuspid lateral annulus using the formula in [6]. Myocardial acceleration