(International Print/Online Journal)

SJIF IMPACT FACTOR: 5.565
PUBMED-National Library of Medicine ID-101739732

ISSN (Print): 2209-2870
ISSN (Online): 2209-2862

International Journal of Medical Science and Current Research (IJMSCR)
Available online at: www.ijmscr.com
Volume3, Issue 6, Page No: 846-851
November-December 2020

Assessment of Left ventricular diastolic function by tissue Doppler imaging during normal pregnancy

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Type of Publication: Original Research Paper
Conflicts of Interest: Nil

ABSTRACT:

Pregnancy, a chronic, natural volume-overload state, has important effects on hemodynamic and echocardiographic variables hence a more accurate assessment of diastolic function of load-independent technique is the needed. Tissue Doppler imaging (TDI) an echocardiographic tool for evaluating diastolic function that is relatively independent of preload. The aim of this study was to evaluate maternal diastolic function using tissue Doppler imaging.

Methods and material: This was a prospective observational study on 110 healthy pregnant women. M-mode, transmitral inflow (peak transmitral flow velocities during early diastole (E wave) and atrial contraction (A wave)) and TDI studies (peak myocardial velocities during early diastole (E' wave) were performed in each trimester and postpartum. The differences in variables between trimesters were analyzed.

Results: The peak transmitral inflow velocity during early diastole (E wave) was significantly reduced during the third trimester and postpartum. However peak flow velocity during atrial contraction (A wave) had increment in the second trimester, but decreased again in the third trimester and postpartum period. Henceforth, E/A ratio progressively reduced as pregnancy advanced. TDI showed that peak myocardial velocities during early diastole (E') had tendency to increase during the second trimester, and then decreased significantly in the third trimester or postpartum period. As a consequence E/E' ratios decreased significantly throughout pregnancy.

Conclusions: This study demonstrates the changes in myocardial relaxation velocity with progression of pregnancy. To detect the early signs of cardiac failure and prevent further deterioration in high risk pregnancy, TDI may be a useful non-invasive technique for monitoring maternal cardiac function to prompt early intervention because of its advantage of being relatively load independent.

Keywords: LV diastolic function, TDI, pregnancy

INTRODUCTION

Throughout pregnancy maternal cardiovascular system undergoes significant changes imposing considerable stress on the pregnant woman's heart. Thromboembolism, hypertensive disease of pregnancy, HELLP syndrome (Hemolysis, Elevated Liver enzymes, and Low Platelets) and amniotic fluid embolism are few of many obstetric complications associated with maternal cardiac dysfunction. With noninvasive techniques, the patterns of maternal cardiovascular changes can be determined throughout pregnancy. Henceforth accurate assessment of cardiac function during pregnancy is required.

Previously, maternal systolic function were the prime focus of studies [1,2]. Diastolic dysfunction precedes impairment of systolic function in the evolution of most cardiac diseases and myocardial relaxation is an energy-dependent process [3,4]. Recent studies have proved that diastolic dysfunction is a major cause of congestive heart failure as more than 50% of people with congestive heart failure have preserved left ventricular systolic function [5,6].

LV diastolic function may be assessed by recording the velocity of flow through the mitral valve and pulmonary veins. Measurement of transmitral inflow velocity by pulsed wave Doppler echocardiography is the most widely employed method of evaluation of left ventricular (LV) diastolic function and is employed in previous studies on pregnant women [7–9]. The mitral inflow profile is affected by a complex interaction of many factors, including myocardial relaxation, ventricular compliance, pericardial restraint, preload and afterload, and myocardial contractility. However, primary events of LV relaxation could not be evaluated with this method. Instead, it measures the impact of altered LV diastolic properties by assessing diastolic flow velocity, which is known to be strongly influenced by ventricular loading conditions [10,11]. Changes in transmitral flow may not be a true depiction of diastolic function since both preload and afterload are significantly altered during pregnancy [9] and above it pregnancy itself involves a chronic volume overload state.

Unlike conventional Doppler, Tissue Doppler imaging (TDI) measures mitral annular velocity giving accurate, reproducible recordings to evaluate the primary events of myocardial relaxation [12-14] independent of preload [14,15]. In this study, our primary objective is to evaluate the changes in diastolic function during pregnancy using relaxation velocities recordings.

METHODS & MATERIAL

It is a prospective observational study carried out in a Coimbatore medical college hospital. During the routine first-trimester early pregnancy ultrasound assessment participants were invited for the study. Maternal echocardiographic examination was scheduled in each trimester and 6–8 weeks post delivery. The gestational age was confirmed by first-trimester ultrasound biometry and also calculated from the last menstrual period. Multiple pregnancies and known maternal medical diseases (such as hypertension, heart disease, diabetes mellitus) were excluded. Written consent was taken. Operator and pregnant women were blinded to the results of the TDI. The study proposal was approved by the Clinical Ethics Committee of the local institution.

Left atrial diameter, LV end systolic and end-diastolic dimensions and ventricular septal and LV posterior wall thicknesses were measured using parasternal long-axis view. LV mass was hence calculated. To assess transmitral inflow velocities from the apical four chamber view the pulse wave Doppler sample volume was placed slightly distal to the mitral annulus between the tips of the leaflets. The following variables were measured: peak flow velocity during early diastole (E) and during atrial contraction (A), deceleration time (DT) of the E wave and the ratio of E to A waves (E/A ratio).

During both contraction and relaxation ventricular myocardial velocities were assessed. The tissue Doppler imaging program was set to the pulsed wave Doppler mode with a sample volume size set at 5 mm. The sample volume was placed at the lateral margin (lateral wall) and at the common septal margin (septal wall) of the tricuspid and mitral annuli from the apical four-chamber view. From the myocardial velocity patterns obtained, peak myocardial velocities during early diastole (Em), atrial contraction (Am) were measured. The ratio of Em to Am and the ratio of transmitral E velocity to Em, an index of left ventricular filling pressure, were calculated.

Statistics

Analyses were performed using the Statistical Package for Social Sciences for Windows version 10.0. As the transmitral inflow and TDI variables were normally distributed, data were expressed as mean ± standard deviation [14-16]. $P < 0.05$ was considered statistically significant. Between trimester differences were analyzed by one-way analysis of variance (ANOVA); least significance difference was used as an *a posteriori* test, when a difference was found with ANOVA.

OBSERVATIONS AND RESULTS

We conducted this observational study on 110 pregnant women. 96 of them followed up in complete

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study and had uncomplicated course of pregnancy. M-mode echocardiographic variables recorded throughout the pregnancy are shown in Table 1.

Table 1 Echocardiographic variables; given as mean (SD)

Parameter	First trimester	Second trimester	Third trimester	Postpartum
Number	110	107	103	96
Maternal pulse (beats/minute)	72.5 (9.2)	77.3 (10.8)*	88.4 (8.9)*	69.2 (9.8)*
Left atrial diameter (cm)	2.7 (0.5)	3.1 (0.4)*	3.1 (0.5)*	3.0 (0.6)*
LV end-systolic diameter (cm)	2.8 (0.4)	2.7 (0.5)	3.4 (0.6)*	3.3 (0.5)
LV end-diastolic diameter (cm)	4.4 (0.5)	4.5 (0.5)	4.8 (0.6)*	4.5 (0.5)*
Septal wall thickness (cm)	0.9 (0.2)	1.1 (0.3)*	1.1 (0.3)*	1.1 (0.2)*
Posterior wall thickness (cm)	1.0 (0.2)	1.2 (0.3)*	1.2 (0.2)	1.0 (0.2)
Ejection fraction (%)	61.0 (10.1)	66.5 (9.2)*	59.5 (11.2)	58.6 (9.9)
LV mass (g)	101.0 (17.5)	105.5 (25.4)	124.2 (31.5)*	108.5 (25.5)

*$P < 0.05$ compared to first trimester. LV, left ventricular.

The result of elastic recoil and active relaxation of the chamber (E wave) and diastolic component of ventricle due to atrial systole (A wave) both reduced during the third trimester and postpartum period. However active relaxation of chamber reduced more signficantly and hence the E/A ratio progressively reduced as pregnancy advanced (Table 2). The interventricular septum and LV mass increased during the pregnancy.

Table 2 Mitral inflow velocity pattern and tissue doppler mitral annular velocities of left ventricular; given as mean (SD)

Parameter	First trimester	Second trimester	Third trimester	Postpartum
E (cm/s)	105.2 (16.8)	101.2 (14.1)	84.9 (13.5)*	87.2 (14.2)*
A (cm/s)	61.2 (10.7)	64.4 (11.1)*	60.8 (11.4)	54.2 (7.3)
E/A ratio	1.7 (0.4)	1.5 (0.4)*	1.4 (0.3)*	1.6 (0.4)*
DT (ms)	159.7 (36.4)	187.2 (28.2)*	186.4 (38.8)*	198.9 (31.5)*
Septal wall				
Em (cm/s)	13.6 (2.3)	14.4 (2.5)	12.8 (1.5)	13.9 (2.1)
Am (cm/s)	7.2 (1.4)	7.5 (1.4)	8.5 (1.2)*	7.6 (1.8)*

Em/Am ratio	2.0 (0.3)	1.8 (0.4)	1.5 (0.3)*	1.7 (0.4)*
E/Em ratio	8.0 (2.3)	7.2 (1.6)	6.5 (1.4)*	6.6 (1.3)*
Lateral wall				
Em (cm/s)	18.5 (3.0)	19.3 (3.1)	17.5 (2.8)	15.8 (3.1)*
Am (cm/s)	12.5 (3.2)	12.2 (3.1)	13.5 (3.2)	11.7 (2.9)
Em/Am ratio	1.6 (0.5)	1.5 (0.4)	1.4 (0.3)	1.4 (0.4)
E/Em ratio	5.8 (1.7)	5.3 (1.1)	4.9 (1.2)	5.6 (1.5)

*$P < 0.05$ compared to first trimester. A, peak flow velocity during atrial contraction; Am, peak myocardial velocity during atrial contraction; DT, deceleration time of the E wave; E, peak flow velocity during early diastole; Em, peak myocardial velocity during early diastole

On tissue doppler mitral annular velocities during pregnancy there was no increase in brisk motion of the mitral annulus (Em) at both lateral and septal wall during second trimester as the chamber expands to accommodate the inflow of blood but was associated with decrease in the third trimester and postpartum period. Since the diastolic annular velocity (Am) increased significantly with advancing gestation the Em/Am ratio decreased significantly. After measuring E and Em velocities, we hence found out that E/Em ratio decreased but within normal limits throughout pregnancy and the postpartum period.

DISCUSSION

Present study designates the LV response to a chronic volume overload state (pregnancy) in healthy women, emphasizing on changes in the diastolic filling patterns of the left ventricle. As gestation advances, the myocardium becomes hypertrophic as we noted by increase in stroke volume and LV wall thickness and LV mass in order to withstand the chronic strain. We observed increase in left atrial size which is an indirect indicator of LV filling rates because of increased venous return to the left atrium (preload) and hence explains increase in Em and Am waves. The increase in left ventricular mass during pregnancy is typical of the physiological myocardial hypertrophy of pregnancy [7,17,18]. The LV hypertrophy that occurs during pregnancy because of increase blood volume and cardiac output can also affect ventricular function by decreasing left ventricular compliance because of geometric realignment of collagen of the myocardium. The peak annular velocity in early diastole (Em) was decreased showing the fall in early diastolic filling rate. Because of myocardial relaxation and compliance changes with aging, different age groups would be expected to have different diastolic filling patterns. With the onset of the second trimester, and even more so the third trimester, atrial contraction became more important to LV filling. This change caused a gradual increase in the A value with each trimester, and the E/A ratio declined in late pregnancy. Therefore, the Am wave increases with gestation and reaches a maximum level in the third trimester, whereas the Em/Am ratio decreases.

The transmitral E: TDI Em ratio is a validated, non-invasive index of pulmonary capillary wedge pressure in non-pregnant people, while E/Em ratio is a marker of left atrial or left ventricular pressure which predominantly remains unchanged but increased after second trimester similar to what Mesa et al., found as normal LV filling pressures during pregnancy [7]. The LV end-diastolic and end-systolic dimensions did not change significantly during or after pregnancy; this finding agrees with the results of Mabie et al [8] but differs from those of other investigators [18,19]. They also reported an increase in A wave and E/A ratio during pregnancy, hence to accomodate increased preload during pregnancy, there was augmentation of atrial

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contractile phase of diastolic filling without any alteration in LV diastolic function.

Another study favouring to our was as reported by Mesa et al. [7] who demonstrated decrease in E wave and E/A ratio and increase in A wave with advancing gestation.

The Peak annular velocity in early diastole primarily depends on LV relaxation. When distolic function is abnormal, the Em is relatively independent of preload and afterload. However when diastolic funtion is normal, Em increases with higher filling pressure and hence it can more accurately reflect ventricular diastolic function during pregnancy. However, in our study the postpartum follow-up time may have been too short to reflect baseline ventricular diastolic function at 6–8 weeks post-delivery, as demonstrated by Robson et al [20] that LV mass continues to decrease for 24 weeks after delivery, though most occurs by 12 weeks postpartum. Clapp and Capeless [21] even demonstrated that LV volume, cardiac output and systemic vascular resistance remained significantly different from prepregnancy levels 1 year post delivery. However oh et al [22] demonstrated similar findings in nonpregnant women of similar age groups as our subjects.

CONCLUSION

Pregnancy has significant effects on mitral inflow and annular velocities during each trimester. There is augmented late diastolic filling phase to accommodate the increase in preload along with systolic contractility. To detect the early signs of cardiac failure and prevent further deterioration in high risk pregnancy, TDI may be a useful non-invasive technique for monitoring maternal cardiac function to prompt early intervention because of its advantage of being relatively load independent. However because of chronic natural volume overload state, future doppler studies of LV diastolic function need trimester matched control subects with longer postpartum follow up.

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