Fetal echocardiographic assessment: impact of gestational age and maternal obesity.

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Abstract

Introduction: To identify the ability to acquire various fetal cardiac views using two-dimensional ultrasound at different gestational age and body mass index (BMI) categories. Material and methods: We performed a prospective observational study among low-risk women with singleton pregnancies attending the University Obstetrics Unit, North Colombo Teaching Hospital, Ragama, Sri Lanka. The ability to obtain satisfactory views for the situs, four chambers (4CH), right and left outflow tracts (ROFT/LOFT), three vessels (3V), aortic arch (AA), ductal arch (DA), and superior and inferior vena cava (SVC/IVC) of fetal heart was studied. Results: A total of 314 eligible pregnant women underwent fetal echocardiography and 288 had complete data. All eight cardiac views were obtained with a 100% success at the gestational age of 18 to 21+6 weeks. All eight cardiac views were satisfactory in more than 97% at the gestational age of 22 to 25+ 6 weeks. BMI was not significantly associated with acquisition of cardiac views at all gestations (Log-rank test, p=0.62). All eight cardiac views were obtained with 50% success at 14 -17+6 weeks and 5.4% success at 11-13+6 weeks. Conclusions: The ability to acquire all fetal cardiac views was best at 18 to 21+6 weeks of gestation, but reasonably successful till 26 weeks. The acquisition of all cardiac views was sub-optimal in early gestations below 18 weeks and for some of the cardiac views after 26 weeks. BMI does not hamper the ability to obtain cardiac views during fetal echocardiography.

Title: Fetal echocardiographic assessment: impact of gestational age and maternal obesity.

Running title: Optimum time and BMI for fetal echocardiography.

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Conflicts of interests

Authors declare that they have no conflicts of interests.

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Abstract

Introduction : To identify the ability to acquire various fetal cardiac views using two-dimensional ultrasound at different gestational age and body mass index (BMI) categories.

Material and methods : We performed a prospective observational study among low-risk women with singleton pregnancies attending the University Obstetrics Unit, North Colombo Teaching Hospital, Ragama, Sri Lanka. The ability to obtain satisfactory views for the situs, four chambers (4CH), right and left outflow tracts (ROFT/LOFT), three vessels (3V), aortic arch (AA), ductal arch (DA), and superior and inferior vena cava (SVC/IVC) of fetal heart was studied.

Results: A total of 314 eligible pregnant women underwent fetal echocardiography and 288 had complete data. All eight cardiac views were obtained with a 100% success at the gestational age of 18 to 21^{+6} weeks. All eight cardiac views were satisfactory in more than 97% at the gestational age of 22 to 25+ 6 weeks. BMI was not significantly associated with acquisition of cardiac views at all gestations (Log-rank test, p=0.62). All eight cardiac views were obtained with 50% success at 14 -17^{+6} weeks and 5.4% success at 11-13^{+6} weeks.

Conclusions: The ability to acquire all fetal cardiac views was best at 18 to 21^{+6} weeks of gestation, but reasonably successful till 26 weeks. The acquisition of all cardiac views was sub-optimal in early gestations below 18 weeks and for some of the cardiac views after 26 weeks. BMI does not hamper the ability to obtain cardiac views during fetal echocardiography.

Keywords: Congenital heart disease; Gestational age categories; Obesity; Prenatal diagnosis; Fetal echocardiography.

Abbreviations

CHD: Congenital heart disease (CHD

BMI: Body mass index

2D: Two-dimensional

4 CH: Four chambers

ROFT/LOFT: Right and left outflow tracts

3V: Three vessels

AA: Aortic arch

DA: Ductal arch

SVC/IVC: Superior and inferior vena cava

ISUOG: International Society of Ultrasound in Obstetrics and Gynecology

Key message

Optimal timing for fetal echocardiography was not based on proper scientific data. This study shows evidence for optimal timing and effect of body mass index for the fetal echocardiography. This has not reported previously.

Introduction

Congenital heart disease (CHD) has been a leading cause of infant death and neurological morbidity (1,2) (3). Screening for CHD in a low-risk population is known to be challenging. The incidence of infant mortality due to congenital heart defects had been varying from about 4/1000 to 50/1000 live births in different studies (4). In Sri Lanka, from 2002 to 2006, 1389 neonatal deaths had been reported due to CHD, which is confined as the major cause of neonatal deaths. Prenatal detection of cardiac anomalies is known to improve fetal well-being and its outcome (5–9) (10), yet it becomes a challenge by the fact that cardiac anomalies fall among the most frequently missed anomalies during prenatal ultrasonography (11). Fetal cardiac medicine had considerably evolved over the past few decades owing to the developments of ultrasound modalities and new therapies (12).

Since most CHD occur in low-risk populations (13), several recent studies have focused on first-trimester fetal heart scans in low-risk populations as well (14–16). A recent study conducted among severe CHD fetuses has highlighted that the quality of cardiac views obtained during the second-trimester standard anomaly scan needs attention to improve the detection rate of CHD (11). In the same study, 50.9% of cases of CHD had missed during the standard anomaly scan. Therefore, it is imperative for an obstetrician to know in which gestation a particular fetal cardiac view/plane can be visualized using ultrasound. This study was aimed to determine the ability of fetal echocardiography to acquire various fetal cardiac views which are used for the diagnosis of fetal cardiac abnormalities, at different gestational age windows and body mass index (BMI).

Materials and method

We performed a prospective observational study at the University Obstetric Unit, North Colombo Teaching Hospital, Ragama, Sri Lanka over a six months period. It is a fetal medicine unit at a tertiary care referral center that receives referrals from everywhere in Sri Lanka. All women aged more than 18 years with singleton pregnancies and registering before 14 weeks of gestation for antenatal care in the unit were recruited. Women with medical disorders (e.g. diabetes mellitus), chromosomal abnormalities, consanguineous marriages, and a previous child with congenital abnormalities were excluded from the study.

All participants underwent a first-trimester ultrasound scan between 11-14 weeks to confirm the gestation age by measurement of crown-rump length. Fetal cardiac views from gestational age 11 to 30 weeks were obtained through two-dimensional (2D) transabdominal ultrasonography. The different timing for the sonographic examination was due to the availability and attendance of pregnant women at various gestational ages and the clinical need of the women who have been referred from elsewhere. All the scans were performed by the same person who has special accredited training in fetal echocardiography (Author TDD). Fetal cardiac images were obtained by "Alpinion EC-15 V4.0" or "Toshiba Aplio 300" ultrasound scanners depending on the availability. The ability to visualize situs, four chambers (4CH); right and left outflow tracts (ROFT/LOFT); three vessels (3V) namely pulmonary artery, ascending aorta and superior vena cava; aortic arch (AA); ductal arch (DA); superior and inferior vena cava (SVC/IVC) of the fetal heart was assessed. The responses were recorded as 'satisfactory view' or 'unsatisfactory view'. Cross-sectional gray-scale imaging was obtained using high-frequency probes. System settings were adjusted to yield a low persistence, a single acoustic focal zone, a relatively narrow image field, and a high frame rate with increased contrast and high-resolution Sonographic examination of the fetal hearts were performed according to the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) practice guidelines (17,18).

Fetal cardiac views at different gestational age windows between 11 and 30 weeks were obtained. The timing of the fetal echocardiography was stratified into five gestational age windows as follows in weeks and days; 11 to 13+6, 14 to 17+6, 18 to 21+6, 22 to 25+6, and 26 to 29+6. Primary outcomes were the ability to acquire eight cardiac views (Situs, 4CH, ROFT, and LOFT, 3V, AA, DA, and SVC/IVC) of the fetal heart at each gestational age window. Descriptive statistics were used to summarise nominal data. Results of the scans were presented as absolute numbers and percentages. Chi-square test was used to see the association between getting the relevant cardiac view and the gestational age window category. Binary logistic regression was then utilized to obtain an adjusted odds ratio with 95% confidence interval for the baseline characteristics. Time to the acquisition of all eight cardiac views for BMI categories was evaluated with Kaplan-Meier estimates and tested with the log-rank test. P-values below 0.05 were considered statistically significant. Ethical approval was obtained from the Ethics Review Committee, Faculty of Medicine, University of Kelaniya, Ragama, Sri Lanka (P/134/10/2016). Informed written consent was taken from the pregnant women.

Results

A total of 314 attended for fetal echocardiography were recruited and only 288 had complete data for the final analysis. The mean maternal age (SD) was 35.1 (5.1) years and the mean BMI (SD) was 23.8 (4.5) m^2/kg. Minimum BMI was 14.2 m^2/kg and the maximum was 43.2 m^2/kg. The mean gestational age (SD) at fetal echocardiography assessment was 20.1 (4.8) weeks. The majority of women in the study were aged more than 35 years (45.5%) and 50% were having a normal BMI as shown in Table 1. Ability of getting all eight cardiac views was statistically significant with gestational age, but not with the maternal age and BMI.

Table 1: Baseline characteristics of the study participants (N = 288).

Ability of two-dimensional ultrasound in acquiring fetal cardiac views

All eight fetal cardiac views were successfully obtained at the gestational window from 18 to 21^{+6} weeks giving a 100% success at all eight views. The ability to get a satisfactory view was significantly lower at lower gestational age windows compared to 18 to 21+6 as demonstrated in Table 2. However, only a slight reduction in obtaining all eight fetal cardiac views was observed between 22 to 29+6 weeks gestation. Seven out of eight cardiac views were satisfactorily visualized in 68.8% of cases from 14 to 17^{+6} weeks. However, this was possible only in 14.3% at the gestational age of 11 to 13^{+6}.

Regarding acquisition of individual cardiac views, the ability of acquisition of four-chamber view was 100% at all gestations except 11 to 13^{+6} weeks (94.6%) and 22 to 25^{+6} weeks (99.1%). The ability for the other cardiac views were very low at the gestation of 11 to 13^{+6}weeks (ranged from 5.4% to 42.9%). The most difficult views at lower gestations were three vessels and superior and inferior vena cava. The ability of the acquiring three vessels and SVC/IVC views also dropped at higher gestations; 96.3% at 26-29^{+6} weeks.

Table 2: The ability of acquisition of each cardiac view at different gestational age windows.

Effect of BMI on the ability of ultrasonography in acquiring fetal cardiac views

Table 3 shows the recruits to each gestational window included women in low, normal and overweight, and obese BMI categories. However, there was no notable difference (Log-rank test, p=0.62) in the percentages of acquisition of fetal cardiac views among different BMI categories noted during the study (Fig. 1), despite obesity being a known compounding factor for unsatisfactory views during an ultrasound assessment.

Table 3: The ability of acquisition of each cardiac view at different BMI categories.

Figure 1: Kaplan-Meier chart showing the probability of

acquisition of each cardiac view at different BMI categories.

BMI: Body mass index

Discussion

A fetal cardiac ultrasound is usually performed between 18 and 22 weeks along with the routine anomaly scan without definitive scientific evidence. This study showed that the ability to acquire all fetal cardiac views was best at 18 to 21^{+6} weeks of gestation, but reasonably successful until 26 weeks of gestation. Acquisition of all cardiac views was sub-optimal in early gestations, below 18 weeks, and for some of the cardiac views (three vessels and SVC/IVC) after 26 weeks. Maternal obesity does not have a significant impact in obtaining cardiac views during fetal echocardiography. The study did not consider the ability to diagnose different fetal cardiac conditions at different gestational ages.

CHD is present in 2 – 6.5 of 1000 live births and is a major cause of morbidity and mortality, with half of these cases being lethal or requiring surgical correction (19,20). Deciding an ideal timing for a fetal cardiac scan should be a balance between the ability to obtain satisfactory views to make a firm diagnosis and essentially not too late that an opportunity is missed for parents to consider their options if there are applicable to the particular diagnosis. We managed to visualize 4CH, LVOT and RVOT views before 18 weeks with more than 80% certainty. There is a theoretical possibility that certain CDH like aortic stenosis evolves slowly over the period of time and eventually end up as cc(FAV) would prevent later development of HLHS, it further facilitate postnatal biventricular circulation (21,22) and multidisciplinary team decision making yields better outcomes (23). Moon-Grady et al. summarizing the database of the International Fetal Cardiac Intervention Registry have mentioned that infants with a fetal diagnosis of aortic stenosis/evolving HLHS, more than twice as many were discharged with biventricular circulation after successful FAV (24). A recent retrospective study has shown 25.3 weeks of mean gestational age at presentation with significant CHDs in 78/350 (25). Another study from Jordan had 26.5 weeks of mean gestational age at the time of the study (26). All these studies were focusing on the sensitivity of detecting cardiac anomalies, nor the success of the scanning at each gestational age periods. So that, the present study is novel providing evidence to select a specific gestational age period to optimize the outcomes of overall scanning and to provide an opportunity to examine each cardiac view more carefully in selected high-risk cases. The present study showed that the effect of BMI in acquiring various cardiac views was not statistically significant. This is in line with previously reported findings regarding the factors that could possibly hamper proper cardiac assessment, such as maternal obesity or fetal position were not found to influence the prenatal detection of CHD (27,28).

Studies evaluating the effect of obesity on the fetal echocardiography is lacking. Our study has shown that BMI does not seem to hamper the ability to acquire the cardiac views and the same has been reported in previous studies (29,30). They have also mentioned the image quality can be difficult in later gestations. Another retrospective study by Cruz et al. have shown that obese women may be good candidates for fetal echocardiograms (31). They have also pointed out that when compared to the standard ultrasound, fetal echocardiograms were more likely to detect a cardiac anomaly in women with increasing BMI ($p=0.07$). Four chamber view was seen in 94.6% cases during the first trimester showing its applicability in early anomaly scanning and fetal echocardiography to detect major CHDs (32). This first trimester screening has made a significant impact on the outcome of CHDs (33). Well-trained general obstetricians have shown to have a comparable reliability in detecting major CHDs during the first trimester (34,35). However, there were criticisms regarding the clinical implications rather than as a research tool, of the first trimester fetal echocardiography and some authors have suggested to defer it until later in pregnancy due to diagnostic challenges (36,37).

For low-risk patients, the best compromise appears to be at around 18 to 21+6 weeks of gestation, which is in keeping with the current practice (17). However, for the patients at increased risk of CHD, such as those found to have substantially increased nuchal translucency or those with a strong family history of the disease, an initial scan to exclude major malformations should be performed by the fetal cardiology expert at 11 to 13+6 weeks, with follow-up at around 20 weeks to exclude more minor defects and those lesions which may become apparent later.

This study showed that the best time to visualise all cardiac views with 100% success, was 18 to 21+6 weeks. However, the rates of acquisition of fetal cardiac views were also acceptable until 26 weeks. Maternal BMI has no significant effect on the acquisition of cardiac views. In addition, it gives an overall idea about the different cardiac views that can be satisfactorily visualised at each gestational age category. This could be used as a guide for the timing of echocardiography when a particular cardiac defect is suspected in the fetus, where specific cardiac view/s are used to confirm the particular diagnosis. More importantly, this study describes which cardiac views can be successfully acquired during different gestational age windows. This has not demonstrated previously. This is much useful when a specific cardiac abnormality is suspected and early diagnosis is necessary to make crucial decisions such as termination or to plan further obstetric care.

Single center data, small sample size, and lack of a few baseline variables such as parity and fetal gender are potential limitations of this study. As we have excluded women who have a history of CHD, effect of absence of parity should be minimal. We did not follow them up for neonatal echocardiography so that a comparing arm is not available to compute sensitivity and specificity analysis.

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Table 1: Baseline characteristics of the study participants (N = 288).

Baseline characteristics (N=288)	**Baseline characteristics (N=288)**	**Ability of acquisition of all eight cardiac views**
Maternal age (Years)	n (%)	aOR (95% CI); p value
18-25	7 (2.4)	0.99 (0.90, 1.09); 0.80
26-30	47 (16.3)	
31-35	103 (35.8)	
35 <	131 (45.5)	
BMI (kg/m^2)	n (%)	1.00 (0.90, 1.10); 0.85
<18.5	33 (11.5)	
18.5 to 24.9	144 (50)	
25.0 to 29.9	80 (27.8)	
>=30	31 (10.8)	
Gestational age window (Weeks)	n (%)	0.53 (0.46, 0.61); < 0.001
11 to 13^{+6}	56 (19.4)	
14 to 17^{+6}	32 (11.1)	
18 to 21^{+6}	66 (22.9)	
22 to 25^{+6}	107 (37.2)	
26 to 29^{+6}	27 (9.4)	

BMI: Body mass index; aOR: Adjusted odds ratio; 95% CI: Confidence interval.

Table 2: The ability of acquisition of each cardiac view at different gestational age windows.

Gestational age in weeks Cardiac view, n (%)	**11 to 13^{+6} (n=56)**	**14 to 17^{+6} (n=32)**	**18 to 21^{+6} (n=66)**	**22 to 25^{+6} (n=107)**	**26 to 29^{+6} (n=27)**	**P value***
Situs	56 (100)	32 (100)	66 (100)	107 (100)	27 (100)	-
4CH	53 (94.6)	32 (100)	66 (100)	106 (99.1)	27 (100)	0.08
ROFT	22 (39.3)	26 (81.3)	66 (100)	104 (97.2)	27 (100)	< 0.001

Gestational age in weeks Cardiac view, n (%)	11 to 13^{+6} (n=56)	14 to 17^{+6} (n=32)	18 to 21^{+6} (n=66)	22 to 25^{+6} (n=107)	26 to 29^{+6} (n=27)	P value*
LOFT	24 (42.9)	27 (84.4)	66 (100)	104 (97.2)	27 (100)	< 0.001
3V	22 (39.3)	28 (87.5)	66 (100)	104 (97.2)	26 (96.3)	< 0.001
AA	21 (37.5)	29 (90.6)	66 (100)	104 (97.2)	27 (100)	< 0.001
DA	21 (37.5)	28 (87.5)	66 (100)	105 (98.1)	27 (100)	< 0.001
SVC/IVC	3 (5.4)	17 (53.2)	66 (100)	105 (98.1)	26 (96.3)	< 0.001
At least seven cardiac views	8 (14.3)	22 (68.8)	66 (100)	104 (97.2)	27 (100)	< 0.001
All eight cardiac views	3 (5.4)	16 (50)	66 (100)	104 (97.2)	25 (92.6)	< 0.001

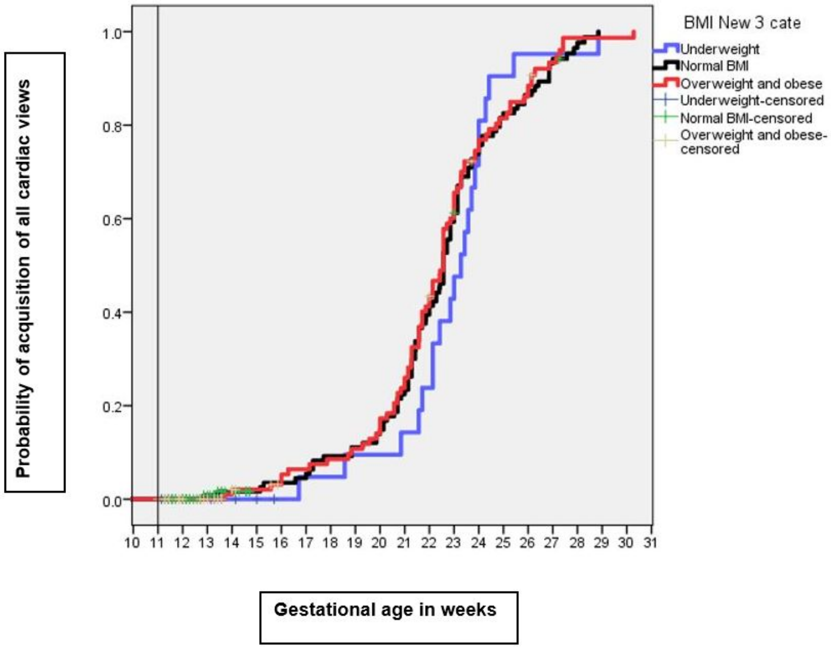
4CH: Four chamber view; ROFT: Right out flow tract; LOFT: Left out flow tract; 3V: Three vessels; AA: Aortic arch; DA: Ductal arch; SVC/IVC: Superior and inferior vena cava.

*Chi-square test.

Table 3: The ability of acquisition of each cardiac view at different BMI categories.

BMI categories Cardiac view, n (%)	Underweight (n=33)	Normal weight (n=144)	Overweight (n=80)	Obese (n=31)
Situs	33 (100)	144 (100)	80 (100)	31 (100)
4CH	33 (100)	141 (97.9)	80 (100)	30 (96.8)
ROFT	27 (81.8)	121 (84.0)	68 (85)	29 (93.6)
LOFT	27 (81.8)	124 (86.1)	68 (85)	29 (93.6)
3V	27 (81.8)	123 (85.4)	67 (83.8)	29 (93.6)
AA	26 (78.8)	123 (85.4)	70 (87.5)	28 (90.3)
DA	26 (78.8)	122 (84.7)	71 (88.8)	28 (90.3)
SVC/IVC	20 (60.6)	105 (72.9)	64 (80)	28 (90.3)
At least seven cardiac views	25 (75.8)	110 (76.4)	64 (80)	28 (90.3)
All eight cardiac views	20 (60.6)	104 (72.2)	62 (77.5)	28 (90.3)

BMI: Body mass index**;** 4CH: Four chamber view; ROFT: Right out flow tract; LOFT: Left out flow tract; 3V: Three vessels; AA: Aortic arch; DA: Ductal arch; SVC/IVC: Superior and inferior vena cava.


Probability of acquisition of all cardiac views
1.0
0.8
0.6
0.4
0.2
0.0
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Gestational age in weeks
BMI New 3 cate
Underweight
Normal BMI
Overweight and obese
Underweight-censored
Normal BMI-censored
Overweight and obese-censored