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Review

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The four-chamber view during fetal heart assessment

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Abstract

Objective: To provide a comprehensive review of the four-chamber view (4CV) during fetal heart assessment, highlighting its significance, technical principles, scanning techniques, and its role in diagnosing congenital heart defects (CHD).

Background: Congenital heart defects are the most common malformations, occurring in 6-8 per 1000 live births. Accurate prenatal diagnosis is essential for effective perinatal management and care, impacting decisions regarding termination of pregnancy or intrauterine interventions. The four-chamber view is a pivotal screening tool during the second trimester anomaly scan, with the potential to detect 40-50% of CHDs.

Methods: This review synthesizes current literature on the sonographic techniques used for 4CV assessment, including real-time two-dimensional echocardiography, color Doppler, and advancements in 3D/4D echocardiography. It also covers the technical principles, such as the use of high-frequency transducers and specific presets, and detailed scanning techniques.

Results: The 4CV enables visualization of the two atria, two ventricles, atrioventricular valves, and septae, allowing for the detection of both cardiac and extracardiac causes of fetal cardiomegaly. The review details the assessment of heart orientation, size, rhythm, and structural characteristics, as well as the role of color Doppler in identifying septal defects and venoatrial and atrioventricular connections. Additionally, it discusses normal anatomical variants and various cardiac abnormalities detectable via 4CV.

Conclusions: The four-chamber view is an essential screening tool for prenatal detection of congenital heart defects, particularly in low-risk fetuses. Proper utilization of 4CV, supported by current guidelines and advanced imaging techniques, can significantly enhance the accuracy of prenatal CHD diagnosis. Further research and clinical training are recommended to optimize the use of 4CV in fetal heart assessment.

Key words: Four-chamber view (4CV), Congenital heart defects (CHD), Prenatal diagnosis, Fetal echocardiography, Ultrasound imaging

Introduction

Congenital heart defects (CHD) are the most frequent malformations and appear with an incidence of 6-8 / 1000 live births. Cardiac abnormalities can occur as isolated entities or in combination with extra-cardiac anomalies. Moreover, they may be connected with chromosomal anomalies or genetic syndromes or not. Prenatal diagnosis is crucial because it can affect perinatal management and care of these infants with hospitalization in expertized departments that can reduce perinatal morbidity and mortality rates. Prenatal diagnosis also give the opportunity for making decisions in severe defects, such as termination of pregnancy or intrauterine operations. Only 20% of the fetuses with CHD had a predisposing factor and the other 80% were low risk for anatomic anomalies. As a result, it is important to examine carefully all fetuses for heart defects as a screening test during the anomaly scan of the second trimester. There are guidelines that determine the basic ultrasound approach and the scanning planes[1].

The four-chamber view (4CV) is considered as one of the most important planes during fetal heart scanning. An abnormal 4CV has a high correlation with CHD and can detect 40-50% of them. The 4CV is the starting plane for the basic and the detailed evaluation of the heart as well. This plane enables visualization of the two atria, the two ventricles, the two atrioventricular valves and the atrial and ventricular septae.

Technical Principals of the 4CV

Sonographic procedures that can be used for 4CV assessment include real time two-dimentional echocardiography (2D), colour Doppler echocardiography, spectral Doppler, M-mode and 3D/4D echocardiography. In clinical practice, mostly, we use 2D and colour Doppler echocardiography. Spectral Doppler is used to quantify flow velocities and M-mode is used to differentiate arrhythmias and evaluate ventricular function. The evolution of 3D/4D echocardiography has entered the STIC technique (spatio-temporal image correlation)[2].

High frequency transducers and specific presets are used for fetal heart evaluation. Presets in B-mode sonography use low persistence, high frame rate and high contrast ratio. We also choose a narrow image field. In colour Doppler, presets should be adjusted with pulse repetition frequency (PRF) between 50 to 100 cm/sec so that the inflow to the heart has not aliasing flow. For the venous flows, PRF should be reduced to 10-30 cm/sec. Colour window should be small and only above the region of interest and colour gain should be fixed as well in order to see the flow inside the vessels and not around their walls[3].

Scanning technique of the 4CV

Determination of the situs

First of all, we obtain a tranverse plane of the fetal abdomen. We should see a complete rib in each of the two lateral abdominal walls in order to obtain a perfect transverse plane. Then, we slide the transducer toward the fetal chest until the 4CV is visualized. In normal situs solitus, the stomach and descending aorta are lying to the left of the spinal column, whereas the vena cava, portal sinus and the gallbladder appear to the right side[4].

The most common situs anomaly is the situs ambiguous, which can subdivided into left and right-isomerism based on defects seen on the spleen, lungs and atria of the heart. Actually, situs ambiguous can not be assigned neither as situs solitus nor as situs inversus. Situs inversus is a condition that visceral organs are reversed from their normal positions. Cardiac problems are more common, but in most

cases people have no medical problems or symptoms[3].

Orientation and size of the heart

Fetal heart lies more horizontally in the thorax in comparison with postnatal life in which the cardiac apex swings inferiorly. The 4CV is at the level of the fourth thoracic rib. Based on the position of the fetus, three types of 4CV exist. These include the apical 4CV, the basal 4CV and the lateral (or axial) 4CV. Evaluation of all anatomic details require more than one type of 4CV and this can be accomplished by scanning fetal heart by different sides of maternal abdominal wall. The apical view allows evaluation of the ventricles, the atrioventricular valves and the atrial and ventricular dimensions. On the other hand, the atrioventricular septae is evaluated better in lateral view[1].

One third of the heart is located inside the right chest and the two thirds of the heart mass is located in the left chest. Normal cardiac axis points to the left with an angle of 45 +/- 15 and occupies 1/3 of the fetal thorax. The width of the heart at the level of the atrioventricular valves in millimeters is similar to gestational weeks. Cardiac dimensions can be evaluated with cardiothoracic circumference (C/T) which is almost the same throught pregnancy (0.45 to 0.5). Increased C/T (greater than 2 standard deviations) means cardiomegaly or reduced chest volume (such as severe pulmonary hypoplasia or skeletal dysplasias) (Figure 1)[5].

Heart rhythm

Fetal heart rhythm should always be evaluated and should be regular with no ectopic beats. The normal range is between 110 to 160 beats/min. In 4CV, we assess the contractility of the left and the right ventricle that should be equal with no paradoxical movements[4].

The atria and the ventricles

The left atrium is the most posterior chamber of

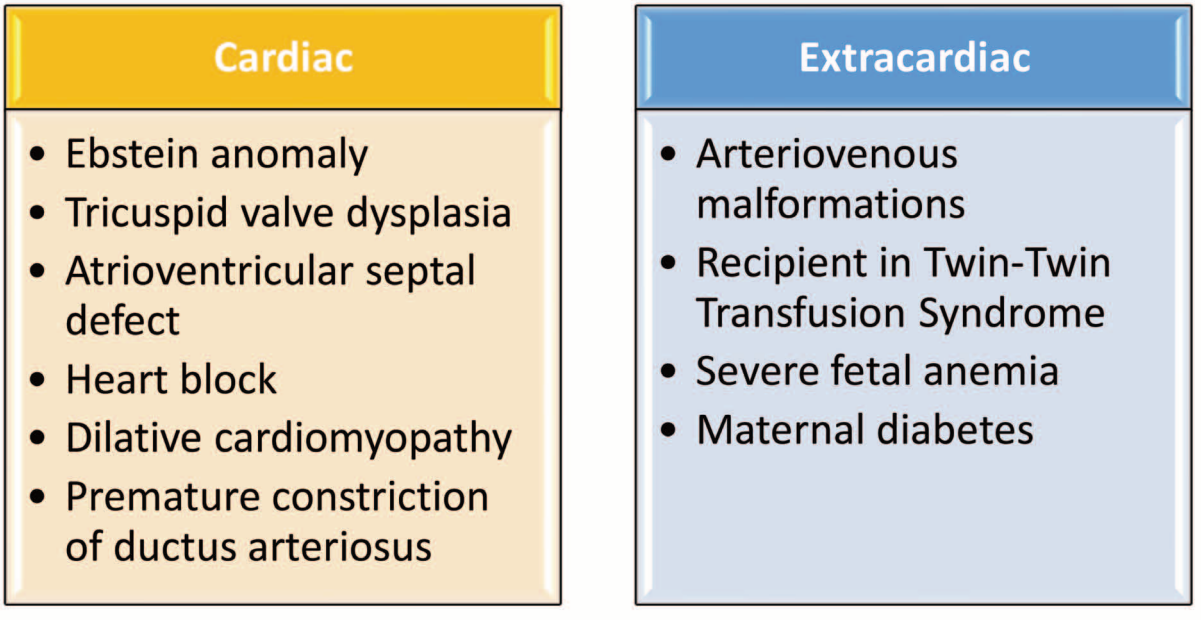

Figure 1. Causes of fetal cardiomegaly

the heart and its two main characteristics are the drainage of the four pulmonary veins and the leaflet of the foramen ovale. The foramen ovale flaps into the left atrium with a right to left shunt. The right atrium communicates with the left atrium with the foramen ovale. The superior and the inferior vena cava enter to the right atrium. Both atriums must be equal in size and are recognized by their venous connections. The left atrial appendages are seen in the 4CV, whereas the right atrial appendages are seen in the bicaval view[2].

The right ventricle is the most anterior cardiac chamber and it lies behind the sternum. The right ventricle is trabeculated and carries the moderator band in the apical part. The left ventricle forms the apex and appears slimmer because of its weaker trabeculation. The atrioventricular valves include the tricuspid and the mitral valve. The tricuspid valve enters more apically on the ventricular septum (1-2 mm) than the mitral valve[5].

The interventricular septum separates the two ventricles. It is wider at the apex and thinner at the level of the atrioventricular valves, because it is muscular at the lower two thirds and membranous at its upper one third. Septal defects are the most common and undiagnosed prenatally cardiac defects and should be confirmed in lateral views. In lateral or otherwise septal views, the normal range of the ventricular septum is between 2 to 4 mm[6].

Colour Doppler in 4CV

Colour doppler helps the evaluation of the venoatrial and atrioventricular connections (Table 1). During the diastole, we notice the blood flow across the patent atrioventricular valves (two separate stripes with no aliasing) and in systole we can rule out the presence of regurgitation. In addition, there is a normal right to left shunt at the level of the foramen ovale. In the lateral view, using the colour doppler we can detect small shunts in the intraventricular septum in cases of septal defects.

Moreover, we can assess at least two of the four pulmonary veins entering the left atrium. In cases of difficult grayscale imaging, as in obese women or in the early gestation, colour doppler can help assessing the four chambers[4].

Normal Variants in the 4CV

Echogenic intracardiac focus (EIF) is a small bright spot seen in the ventricular cavity at the level of the papillary muscle. Its incidence is 4% and in a patient with a low-risk first-trimester scan and without additional findings in the anomaly scan, it can be considered a normal anatomical variant and no further intervention is required. The presence of EIF in a high-risk patient for aneuploidy requires genetic counseling to proceed with

Table 1. Cardiac Abnormalities

Normal 4CV	**Abnormal 4CV**
Tetrallogy Fallot	Mitral/aortic atresia
Transposition of the great arteries	Tricuspid/pulmonary atresia
Double outlet right ventricle	Ebstein anomaly
Ventricular septal defects	Atrioventricular septal defect
Common arterial trunk	Large ventricular septal defects
Mild semilunar valve stenosis	Single ventricle
Aortic arch abnormalities	Severe aortic/pulmonary stenosis
	Severe coarctation of the aorta
	Cardiomyopathies
	Heart tumors
	Total anomalous venous connection

non-invasive or invasive diagnostic procedures[3].

Small pericardial fluid (less than 2 mm in thickness) is another normal variant. Pericardial effusion larger than 2 mm requires careful evaluation of the fetal heart anatomy and a detailed fetal anatomical evaluation[6].

During the third trimester, sometimes the right ventricle may appear bigger than the left. This finding requires careful heart assessment because there may be coarctation of the aorta or other heart defects. A small disproportion, however, may be a normal anatomic variant. In any case, we should evaluate the great vessels, the aortic arch, and the pulmonary veins very carefully[1].

Normally, the tricuspid valve is more apical compared to the mitral valve. The presence of linear insertion of the atrioventricular valves on the ventricular septum can be a normal anatomical variant, but we must evaluate the fetal heart well to conclude AVSD. This anatomical variant with the absence of septal defects has also been found in fetuses with trisomy 21[2].

Vessels Behind the Heart

There is only one vessel behind the heart on the left side, the descending aorta. Anterior and close to the aorta is the esophagus, a small echogenic structure that can be seen during fetal swallowing. On the right side of the aorta, there is a small vessel (one-third of the aorta size), the azygos vein. Drainage of the azygos vein to the superior vena cava can be noticed in the three-vessel tracheal view. The azygos vein can be dilated in abnormal cases and can be close in size to the aorta. Moreover, the position of the descending aorta reflects the position of the aortic arch. In cases of a right aortic arch or double aortic arch, the descending aorta is seen to the right of the spine or anteriorly[2].

4CV in the First Trimester Scan

Fetal heart assessment is possible from the first trimester between 11 to 14 gestational weeks with transabdominal or transvaginal ultrasound examination. Indications of early fetal heart assessment include cases of increased nuchal translucency and families with a history of heart defects. Tricuspid insufficiency is another indication. Detection of abnormalities depends on the examiner's experience, the fetus's position, and other factors such as the mother's obesity. In experienced hands, detection rates can reach 70%. Early fetal echocardiography has to be performed in specialized centers and should not replace echocardiography around the 20th gestational week[3].

4CV in Fetal Growth Restricted Fetuses

Fetal growth restriction is a clinical entity in which fetuses fail to achieve their growth potential. Diagnosis is made with ultrasound biometry and estimated fetal weight (EFW) is less than the 10th percentile or abdominal circumference (AC) is less than the 10th percentile. Some studies have tried to evaluate cardiac dimensions in normal and fetal growth restricted fetuses to assess if altered cardiac diameters can predict adverse perinatal outcomes in FGR fetuses. In 2012, Uerpairojkit et al. investigated the effect of FGR on fetal cardiac dimensions. Cardiac circumference and cardiac area were measured in 49 FGR and 143 normal fetuses, and the results showed that cardiac dimensions did not differ significantly between the two groups. On the other hand, in 2019, Hobbins et al. performed a retrospective study of 50 FGR fetuses between 25 to 37 gestational weeks and measured the largest basal-apical length, the transverse width, the right and left ventricular chamber areas, and the right ventricle/left ventricle area ratio. Abnormalities in cardiac shape and size were found in FGR fetuses. The shape of 4CV was more globular in FGR fetuses compared with the controls. As a result, the study concluded that dimensions of the four-chamber view acting as surrogates for ventricular

dysfunction may identify fetuses who could benefit from further comprehensive testing and future preventive interventions. Studies have controversial results, so further investigation is required[5].

Fetal Cardiac Function

Fetal echocardiography has evolved in recent years, and advances in ultrasound have achieved the evaluation of the pathophysiology of fetal circulation. As a result, beyond anatomical abnormalities, we can assess fetal cardiac function. Heart failure is the inability of the fetal heart to supply sufficient blood flow to fetal organs. In the late stages of heart failure, cardiomegaly, atrioventricular insufficiency, and fetal hydrops appear. In the initial stages, the fetal heart manages to adapt, resulting in a long subclinical period in which cardiac remodeling occurs. Functional echocardiography can help identify fetal heart dysfunction in cases of intrauterine growth restriction, twin-to-twin transfusion syndrome, hydrops, fetal arrhythmias, maternal diabetes, and congenital diaphragmatic hernia[6].

The cardiac cycle can be divided into five periods:

1. Isovolumetric period: The first phase of diastole. The myocardium relaxes but the atrioventricular valves have not opened yet.
2. Early diastole: Atrioventricular valves open and the blood from the atria fills the ventricles in a passive manner.
3. Late diastole (Atrial contraction): The atria contract and complete the filling of the ventricles.
4. Isovolumetric contraction period: The beginning of systole. The time period between the atrioventricular valves closure and before the opening of the aortic and pulmonary valve.
5. Ejection period: The opening of the aortic and pulmonary valve and blood is ejected from the ventricles.

Techniques for the assessment of cardiac function include 2D imaging, M-Mode, 2D speckle tracking, and 4D-STIC[6].

2D Imaging permits evaluation of fetal heart anatomy and structure and also signs of remodeling. In cardiac remodeling, there are changes in size, shape, structure, and physiology of the heart. 2D images permit measurements of cardiac dimensions (atrial size, valve diameters, ventricular dimensions)[3].

Doppler allows measuring ventricular blood outflow and inflow. The E/A ratio is used to evaluate diastolic or ventricular relaxation. The sample gate is placed above the atrioventricular valves in the 4CV and a biphasic wave is displayed normally. The E wave represents myocardial relaxation (passive diastole) and the A wave represents the atrial contraction during ventricular filling. The ratio E/A is usually less than 1. E/A velocities increase with gestational age and the tricuspid valve has higher velocities than the mitral valve[1].

The myocardial performance index (MPI) reflects total cardiac function. The MPI is measured in the 4CV by placing the gate of the spectral Doppler on the median wall of the ascending aorta including the aortic and mitral valve. Then 3 time periods are measured: the isovolumetric contraction time (ICT), the ejection time (ET), and the isovolumetric relaxation time (IRT). MPI is calculated as (ICT + IRT) / ET. Normal values increase throughout gestation[2].

M-mode can be used for the evaluation of cardiac dimensions and shortening and ejection fractions. In the transverse 4CV, we can measure the end-diastolic and end-systolic diameters to calculate the above fractions[2].

Conclusions

Congenital heart diseases affect not only high-risk fetuses but mostly low-risk ones. The prenatal diagnosis of CHD should be achieved with a simple general screening. The four-chamber view with the 2D

B-mode is a very good screening tool. When gestational age is more than 20 weeks and the examiner is experienced, correct visualization is frequent. When the 4CV seems abnormal or cannot be visualized adequately, further fetal echocardiography should be performed. If fetal heart assessment is limited only to the 4CV, then a proportion of critical heart defects will not be diagnosed. In the 80s, fetal heart assessment was limited to the 4CV, but in the last 25 years, the incorporation of views of the great vessels has been recommended as part of the routine screening examination.

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