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Fetal Cardiac Dimensions Normograms from 14 weeks of Gestation to Term in the Egyptian Population

Esraa.A.Marzouk, Hesham.E.El sheikh, Sherif.M.Eltaher, Yehia.S.Edris and Wael.M.Abd El Khalek
Radiology Dept., Faculty of Medicine, Benha University, Benha, Egypt.
E-mail: marzoukesraa167@gmail.com

Abstract
It is very crucial to discover congenital heart disorders (CHDs) as early as possible during pregnancy. Early detection of CHDs ensures a seamless transition between prenatal and postnatal treatment, greatly reducing mortality and morbidity rates and assisting families in making educated choices regarding the pregnancy. For better results, medical intervention must begin as soon as possible after delivery. To improve prenatal treatment and outcomes, it is crucial to quantify the fetal cardiac, ventricular, and atrial dimensions accurately in order to monitor and understand the fetal adaptability to unfavorable settings. One of the most useful noninvasive techniques for assessing the cardiac architecture of fetuses during the prenatal stage is still two-dimensional (2D) echocardiography. Currently, one of the most useful noninvasive techniques for measuring the cardiac architecture of fetuses throughout pregnancy is two-dimensional (2D) echocardiography. Studies examining measures of normal heart anatomical dimensions are few, particularly in the Egyptian population. The lack of baseline fetal cardiac dimensions makes it challenging to precisely identify and track minute changes in heart morphometry in response to a challenging environment.

Keywords: Congenital Heart Diseases, Fetal Cardiac, Cardia Measurements

Introduction

Embryonic blood circulation begins during 23 days of growth and development, when the embryo's single heart tube begins to beat; this process continues until 30 days of embryonic development, when the cardiovascular system begins to operate as a four-chambered structure. The heart and blood vessels of a developing human embryo are completely absent in the first twenty days of life. During the next month, the heart and great vessels finish developing and resemble what they would look like at full gestation. [1].

Fetal heart development

By the twenty-second day of development, when the embryo is about 2.5 to 3 mm long, the two tubular structures that make up the heart finally unite to create a single, slightly curved tube. The heart tube joins the growing arch system, vitelline veins, and umbilical veins at this point in time.As the heart continues to grow, its one tubular chamber expands and contracts in alternate patterns, eventually becoming five dilations—the sinus venosus, atrium, ventricle, bulbus cordis, and truncus arteriosus—in a clockwise direction from the base of the heart toward the top of the skull. [2].

As the atrioventricular-bulbar loop takes shape, the heart enters its second developmental stage. Around the 23rd day of development, the primitive heart starts to loop. This happens when the cephalic part of the heart tube bends ventrally and to the right, while the caudal atrial part begins to curve dorsocranially and to the left. **(Fig.)** [3].

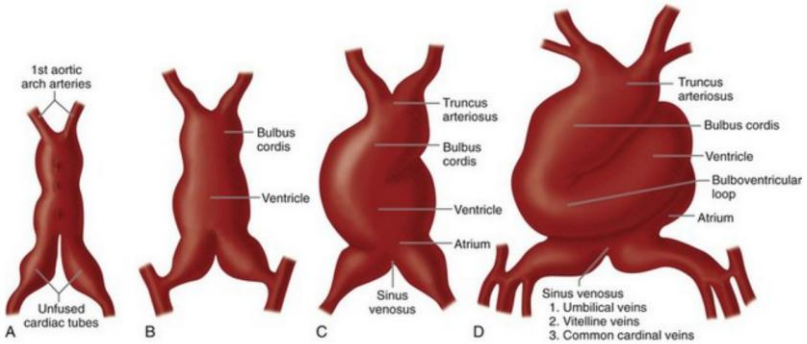

Fig. (1) Formation of the first cardiac stent.A: The path of cephalad to caudad fusion is used by paired cardiac tubes.B: Early stages of chamber differentiation with a fused cardiac tubeC: Right ventricular bulgotomy.D: The heart tube after the last bulboventricular loop. The heart's chambers are well defined. [4]

The right and left segments of the sinus venosus are carried along by the newly created common atrium as it reaches the pericardial cavity as the cardiac loop continues to bend. The left side of the common atrium connects to the early embryonic primitive ventricle via the atrioventricular canal, and the atrium moves to a more dorsal and cranial location. **(Fig.)** [5].

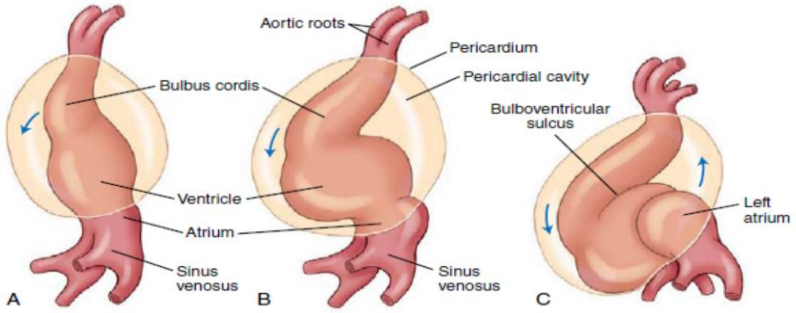

Fig. (2) Around 22 days (A), 23 days (B), and 24 days (C) after fertilization, the atrioventriculobulbar loop forms. Along with the formation of this loop, the pericardial cavity is entered by a shared atrium. [6]

In time, the primitive ventricle will transform into the left ventricle, while the right ventricle will be formed from the proximal bulbus cordis. Both ventricles' outflow tracts are formed by the enlarged distal bulbus cordis, while the major vessels' roots are formed by the truncus arteriosus. **[7].**

The fetal circulation

The fetal circulation is an entirely transient event, not replicated at any point in later life, and structurally and functionally distinct from the pediatric and adult circulations. Unlike in the adult, fetal gas and metabolite exchange takes place in the placenta, the placenta must therefore receive deoxygenated blood from the fetal systemic organs and return its oxygen rich venous drainage to the fetal systemic arterial circulation **[8].**

There are three unique fetal cardiovascular connections:

1) **The ductus venosus (DV):** a connection between the umbilical vein and the inferior vena cava (IVC).
2) **The foramen ovale (FO):** a communication between the right (RA) and the left atrium (LA).
3) **The ductus arteriosus (DA):** a connection between the pulmonary artery and the aorta) that are important for maintaining this parallel circulation **(Fig)** [9]

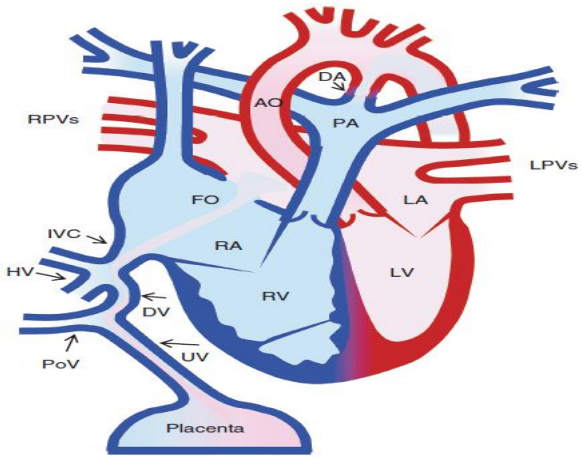

Fig 3: The foetal circulation is normal. DV stands for ductus venosus, PoV for portal vein, AO for ascending aorta, PA for pulmonary artery, DA for ductus arteriosus, IVC for inferior vena cava, RA for right atrium, LA for left atrium, RV for right ventricle, LV for left ventricle, AO for ascending aorta, PA for pulmonary artery, DV for ductus venosus, DAO for descending aorta, and IVC for inferior vena cava. A. Foramen ovale; B. Right pulmonary veins; C. Left pulmonary veins [10]

Therefore, three fetal channels must be functionally closed in order for the cardiovascular system to adapt to newborn life:

- **Ductus venous**

Because of the reduction in umbilical venous blood flow that occurs after umbilical cord clamping, the ductus venosus stops functioning normally. Permanent closure of the ductus venosus occurs within the first two weeks after birth, albeit it is more sluggish in premature babies compared to term newborns. **[11].**

- **Foramen ovale**

During gestation, the pressure in the right atrium is greater than that in the left atrium. As a result, the foramen ovale stays open. After the lungs are oxygenated, the reduction in PVR raises the flow of the pulmonary arteries, which raises the return of the pulmonary veins to the left atrium.

The foramen ovale seals and merges with the interatrial septal wall due to the rise in left atrial pressure and the cessation of directed flow from the ductus venosus. As a result of this process, the foramen ovale becomes functionally useless shortly after birth. The foramen ovale closes for good throughout infancy and early childhood. [12].

- **Ductus arteriosus**

The ductus arteriosus begins to shut shortly after delivery in full-term neonates who do not have congenital cardiac disease. It is likely that a number of processes, including an increase in arterial oxygen content, reduction of endogenous prostaglandin E2 production, plasma catecholamines, and brain communication, moderate the smooth muscle contraction inside the ductus. Also, since the placental circulation isn't there, systemic vascular resistance is higher and pulmonary vascular resistance is lower, which causes ductal blood flow to be inverted. More than 90% of full-term babies have the ductus completely closed after three days. [13].

Fetal echocardiography

In order to detect and describe fetal cardiac abnormalities before to birth, a thorough sonographic assessment is performed, which is often known as fetal echocardiogram. The "basic" and "extended basic" fetal cardiac screening criteria, as outlined for the four-chamber view and outflow pathways, are expanded upon in this specialist diagnostic process (International Society of Ultrasound in Obstetrics and Gynecology, 2006). [14].

- **Indications**

For pregnancies that are considered high-risk for congenital heart defects (CHD), fetal echocardiography is often done. Despite this, almost 50% of afflicted babies are delivered to moms who had no prior history of the disease. All pregnant women should have access to an adequate screening process, since this highlights the necessity. When the probability of prenatal CHD is more than 1%—roughly three times the background population risk—it is generally advised to send the patient for fetal echocardiography. Additional testing with fetal echocardiography would not be necessary for patients whose illness probability is lower than the background level after normal screening ultrasound findings. [15].

Table (1) **Indications for feta echocardiography in order of frequency of referral** [16]

Family history of congenital heart disease
Maternal diabetes mellitus
Suspicion of congenital heart disease on obstetrical ultrasonography
Arrhythmia
Extracardiac congenital anomalies
Systemic lupus erythematosus
Chromosome anomaly
Teratogen exposure
Other

- **Timing of fetal echocardiography**

The best time to do a thorough trans-abdominal fetal echocardiogram is between the ages of 18 and 22 weeks. Technological advancements in ultrasonography have made it possible to assess the heart function of a developing foetus as early as twelve to fourteen weeks into the pregnancy. Babies who are at high risk of having a heart defect benefit greatly from these kinds of prenatal examinations. During the 18th to 20th week of pregnancy, the majority of significant cardiac abnormalities may be discovered. The inability to identify semilunar valve stenosis and atrioventricular valve backflow does not occur until week 30 or later, however. Hence, at week 30, it is recommended to have an additional cardiac test. Up to around 34–36 weeks of gestation, the defective heart is often evaluated serially every 2–8 weeks (based on the lesion and clinical issues). [17].

Cardiac examination

- **The four-chamber view**

Obtaining the four-chamber image of the foetal heart is not only the simplest but also the most critical thing to do. From the transverse abdominal view, it may be seen well by cranially moving the transducer. Accurate interpretation of the four-chamber perspective relies on its proper acquisition. To get an accurate ultrasound of the foetal heart, the US beam has to be positioned in the proper orthogonal plane. A perfectly transverse plane that shows the whole width of at least one rib is the right one to use. Having more than one rib suggests that the US beam isn't perfectly perpendicular to the T-shape. [18] .

Based on the location of the developing baby, a doctor may order one of three different four-chamber views: an axial view, a basal view, or a long-axis view. Unlike the third picture, when the US beam is perpendicular to the septum, the first two show the beam running parallel to the ventricular septum. [19].

Assessment of the atrium and ventricles in the four-chamber perspective. Atrial and

ventricular septal architecture, atrioventricular (AV) valve shape, pulmonary venous connections, and the location and axis of the heart may also be seen. Vertebral valve regurgitation, foramen ovale flow direction, ventricular septum integrity, and pulmonary venous connections may all be evaluated using color Doppler. [20].

- **Left ventricular outflow tract view (LVOT)**

Following the four-chamber view, this is the most crucial perspective. In order to see the LVOT while using the four-chamber view, the transducer is pointed towards the right side of the baby's shoulder. From the lateral four-chamber view, you may also access the LVOT view. This perspective requires the observation of aortic valve motion and the confirmation of septo-aortic continuity. As the arch, the two outflow tracts intersect at their sources, and the typical aorta first travels to the right, then crosses back over to the left. On color Doppler, they show polarized color signals coming from the surface. [21].

In this view, the aortic valve can be recognized and a detailed evaluation of its size and mobility can be performed. Even, the thickness of the septum is measured by the five chamber (LVOT) view (IVS raging between 2- and 4-mm during gestation [22].

- **The right ventricular outflow tract view (RVOT)**

From the position for a four-chamber view, the probe is slid cephalad and rotated towards the left fetal shoulder to obtain the RVOT view. This reveals the RVOT in its long axis. The pulmonary valve motion can be appreciated within the RVOT. On rotation toward the left. The bifurcation of the pulmonary artery can be seen. Color and pulsed Doppler evaluation of the RVOT is done to look for aliasing at the pulmonary valve. The peak systolic velocity in the pulmonary artery can be obtained with pulsed Doppler. In the right ventricular outflow view, structures of the right side of the heart are displayed arranged around the aortic root, Behind the aortic root, a section of the left atrium and the atrial septum is imaged [23].

Cardiac biometry and measurement data

In order to monitor the fetus and avoid cardiovascular complications, echocardiography may be used during pregnancy to detect even small changes in heart morphometry. Rather than relying on the size of the heart structures, aberrant cardiac connections are often used as the main indicator for the diagnosis of congenital heart disease. Nevertheless, the size of the arteries has a significant role in the diagnosis and prognosis of some cardiac disorders, such as aortic coarctation, pulmonary valve stenosis, and aortic valve stenosis. The comparison of the actual size of a valve or vessel with the projected size at a certain gestational age (GA) might be critically relevant. In order to monitor the fetus and avoid cardiovascular complications, echocardiography may be used during pregnancy to detect even small changes in heart morphometry. Rather than relying on the size of the heart structures, aberrant cardiac connections are often used as the main indicator for the diagnosis of congenital heart disease. Nevertheless, the size of the arteries has a significant role in the diagnosis and prognosis of some cardiac disorders, such as aortic coarctation, pulmonary valve stenosis, and aortic valve stenosis. The comparison of the actual size of a valve or vessel with the projected size at a certain gestational age (GA) might be critically relevant. [24].

Two-dimensional (2D) echocardiography is currently one of the most practical noninvasive methods to measure cardiac structures for fetuses prenatally and children postnatally. Reference values for fetal cardiac dimensions derived from 2D echocardiography are well-established, allowing quantification and comparison of size of cardiac structures in differing subgroups of a disease [25].

Assessment of the four-chamber view involves careful evaluation of specific criteria including:

1. Heart rate and rhythm

Normal fetal heart rate ranges from 110–160 beats per minute (BPM) however this does vary some with gestational age. Though persistent bradycardia is defined as heart rates below 100 BPM and tachycardia as heart rates over 180 BPM, in general persistent fetal hearts in the 100–110 range as well as 160–180 BPM range with diminished variability is not normal and merits further evaluation [26].

2. Cardiac Position

The normal heart is situated in the midline, apex directed left. A line that bisects the chest from spine to sternum should pass through the left atrium and right ventricle. Subtle cardiac displacement may be apparent only when checking this line [27].

3. Cardiac axis

The orientation of the cardiac axis is independent from the position of the heart. Therefore, for each heart position, orientation of the axis can be to the left, to the midline, or to the right and must be described separately. Anomalies of the cardiac position or axis can occur in isolation, although many anomalies alter both. Abnormal axis increases the risk of cardiac malformations, especially those involving outflow tracts. This may also be caused by extra-cardiac anomalies of the lung or diaphragmatic hernias [28].

4. Cardiac size

The cardiac size relative to thorax can be evaluated from cross sectional images through the fetal chest with measurements of cardiothoracic diameter, area and circumference ratios [29].

- **Cardio-thoracic diameter**

The diameter of the heart can be compared to that of the thorax in the following way:

$$= \frac{\text{Anteroposterior + transverse diameter of the heart/2}}{\text{Anteroposterior + transverse diameter of the thorax/2}}$$

Normal ratio is 45–55% and is independent of the gestational age [30].

- **Cardio-thoracic circumference ratio**

The ratio of the two circumferences, the one of the heart and the other of the thorax, is known as the C/T circumference ratio. This measurement is best accomplished using a cross-sectional view when all of the thorax can be seen, including a clear view of the four chambers, all of the ribs, and the absence of abdominal content (Fig.2-5). At 17 weeks and term, the typical C/T circumference ratio is 0.45, which is fairly consistent.Any value more than 0.5 is considered abnormal. [31].

- **Cardio-thoracic area ratio**

The C/T area ratio, which compares the cardiac and thoracic areas, is another alternative. Similarly, this ratio remains very stable during pregnancy, often falling within the usual range of 0.25 to 0.35. Differentiating between a normal-sized heart in a tiny thorax and an enlarged heart in a normal-sized thorax is crucial when the C/T ratio is aberrant. A comparison of the measured chest circumference with the age-related normal values may be used to achieve this differentiation. [32].

- **Cardiac measurements**

Except for atrial dimensions, which are determined at end-systole, all cardiac measures are taken during end-diastole. When the ventricles enlarge to their maximum size—at the end of diastole—the atrioventricular valves collapse. At the end of systole, when the atriums are at their biggest, the atrioventricular valves open. [33].

During end-systole, 2D pictures are taken of the atrium in either an apical or basal four-chamber view to assess its diameter and area at maximum distension. The atrioventricular valve annulus and pulmonary veins and arteries are not included in atrial measurements. For the purpose of measuring the atrial diameter along a longitudinal axis and the atrial diameter across a transverse axis, the atria are divided into four approximately similar squares. [34].

The diameter of the foramen oval (FO) is measured at the end of systole, when the semilunar valves open and the atrioventricular valve closes. [35].

2D pictures taken at end-diastole from either the apical or basal four-chamber perspective are used to quantify the diameters and areas of the ventricles. At the level of the atrioventricular valves, the basal diameters of the left and right ventricles are measured.In order to get the longitudinal diameters, the inner myocardium is measured from its basal diameter all the way to its apex. [25].

At the conclusion of diastole, just before the atrioventricular valve closes, the diameters of the mitral and tricuspid valves are measured. 2D pictures taken at end-diastole using a transverse 4-chamber view are used to estimate the thickness of the myocardial wall. [36].

The aortic and pulmonary annulus diameters are measured at the level of the valve in diastole (when the valve is closed) in the left ventricular outflow tract (LVOT) and right ventricular outflow tract (RVOT) perspectives. At their meeting point at the widest systolic width, the diameters of the transverse ductus arteriosus (DA) and the transverse aortic isthmus (AI) are measured in the three-vessel-trachea view. From one end to the other, all measurements are taken. [37].

Conclusion

Focus on the Size of the Fetal Heart Egyptian Pregnancy Normograms from 14 Weeks to Full-Term

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