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Fetal Anatomy: Chest

1. **Sonographic evaluation** of the fetal chest includes:
   a. Symmetry of bony elements of the thorax
   b. Chest size in relationship to the fetus in general and the fetal abdomen in particular.
   c. Evaluation of the fetal heart.
   d. Pulmonary echo texture
   e. Presence and integrity of the diaphragms

2. **Thorax:** Axial and coronal sections demonstrate integrity of thorax, fetal breathing movements, and overall size and shape**.**
   a. Bony elements of the thorax include:
      i. Clavicles
      ii. Ribs
      iii. Scapulae
      iv. Vertebral bodies
      v. Mediastinum

3. **Lung:** Coronal section demonstrates relationship of pulmonary parenchyma to heart and chest wall**.**
   a. Lung parenchyma is normally slightly more echogenic than that of adjacent abdominal parenchymal viscera, i.e., spleen and liver.
   b. Lungs separated from abdominal viscera by hypoechoic, curvilinear diaphragms.
   c. Appears solid and relatively homogenous.

Fetal Echocardiography – Introduction

1. **Technique and Normal Anatomy**

When evaluating the fetal heart, the fetal position should be documented. Then, the stomach side and the relation of the suprahepatic portion of the inferior vena cava to the right atrium should be noted. Fetal cardiac malposition is extremely complex. The ten cardiac segments may be greatly simplified into three main cardiac segments that are diagnostically important:

   a. The visceroatrial situs, which is important in localization of the atrium;
   b. The ventricular loop, which is important in diagnosing the relation of the ventricles to the atrium;

c. The truncus arteriosus, which is important for diagnostic understanding of the relation between the great arteries and the ventricle.

Visceroatrial situs abnormalities may be divided into three separate types:

a. *Situs solitus* is the normal, non-inverted type in which there is a normal visceral situs with the stomach to the left. The morphologic right atrium is right-sided and the morphologic left atrium is left-sided.
b. *Situs inversus* is the exact mirror image of situs solitus. The stomach is to the left, but the morphologic right atrium is left-sided, and the morphologic left atrium is right-sided in an inverted anatomic pattern.
c. *Situs ambiguous* is an anatomically indeterminate type of visceral situs in which the liver is usually located in the midline with the stomach located either to the left or the right. This has been typically divided into what can be thought of as the *asplenia* syndrome and the *polysplenia* syndrome. Asplenia syndrome is often thought morphologically to be two right atria. Although this is not completely true, it is important to recognize this abnormality because most of these fetuses present with severe cyanosis as a newborn from congenital heart disease. Alternatively, *polysplenia,* often thought of as bilateral left-sidedness, usually presents with less severe cardiac problems The relation of the atria to the ventricle may be important to recognize prenatally. Anatomically, the right atrium may open into the right ventricle in a normal or concordant relation, or it may be discordant, with the right atrium opening into the left ventricle. Furthermore, there may be other abnormalities of the relation of the atria to the ventricles, including abnormal positions of the tricuspid valve within the right ventricle, such as occur with Ebstein's anomaly.
d. Finally, an abnormal relation of the outflow tracts may be diagnosed prenatally. The most common abnormality of this type is transposition of the great vessels in which the right ventricle gives rise to the aorta and the left ventricle supplies the pulmonary artery.

(From: McGahan, JP Diagnostic Obstetric Ultrasound LB Lippincott, 1994)

2. Four Chamber View

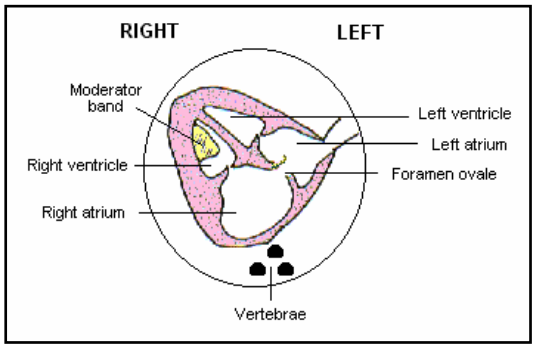
After determining that the heart is located within the left side of the chest, the fetal thoracic spine is identified and a scan is obtained transverse to the thorax to obtain a four-chamber view of the heart. Anatomically, the right ventricle is behind the sternum, and the left ventricle is inferior and to the left of the right ventricle. Generally, the right and left ventricles maintain about a 1:1 ratio as identified on sonograms during diastole at the atrial ventricular valve region. This may be assessed on real-time ultrasound, and it precise measurements are to be made; documentation may be done with M-mode ultrasound. M-mode biventricular measurements obtained during ventricular diastole are compared with the thoracic circumference and may be helpful to predict cardiomegaly or pulmonary hypoplasia. Regardless of the fetal position, the interventricular septum transverses a plane of about 35 to 45 degrees with a line drawn between the spine and the sternum. The heart

should occupy about one third of the fetal thorax. Specific heart chambers can be identified as follows:

a. ***Right atrium*** may be identified when scanning in different anatomic planes and noting the hepatic veins, inferior vena cava and superior vena cava draining into that structure. The foramen ovale is noted opening from the right atrium into the left atrium.
b. ***Left atrium*** is posterior in location in comparison to the right atrium, with the foramen ovale opening into this chamber. The position of the spine is noted, with the left atrium lying close to the vertebral column.
c. The right atrium drains into the ***right ventricle***. The right ventricle is retrosternal in location, with the tricuspid valve lower in position within the right ventricle than the mitral valve is within the left ventricle. There is also a large echogenic structure lying within the right ventricle, the muscular moderator band. The right ventricle lies retrosternal in location
d. The left atrium drains into the ***left ventricle***. Papillary muscles are identified within the left ventricle. Echogenic bright spots may be identified within the left ventricle. These are thought to be attachments of the papillary muscles and are not abnormal. The mitral valve is in a higher location within the left ventricle than the tricuspid is within the right ventricle. The apex of the heart and the interventricular septum are just cephalad to the fetal stomach.

Four chamber view: Demonstrates:

* Apex of heart points 45° to left anterior chest wall
* Ventricles approximately same size (R > L later in pregnancy)
* Flap of foramen ovale opens into left atrium
* Prominent moderator bands present in apex of right ventricle
* Valves separate both atria from ventricles

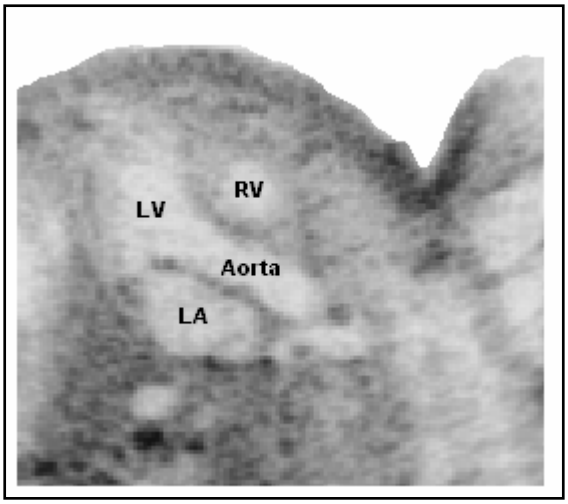


3. Long Axis View (LVOT)

In most fetuses, the interventricular septum lies perpendicular to the transducer beam. The relation of the aorta to the left ventricle is best evaluated by the left ventricular long axis view of the fetal heart. This view is obtained by rotating the transducer from the four-chamber view into a plane angled from the fetal stomach toward the right shoulder of the fetus. This view is helpful to evaluate the relation of the proximal aortic arch exiting the left ventricle to the right pulmonary artery lying inferior to it.

LVOT: Also called extended four-chamber view. Demonstrates aortic and left ventricular continuity, left atrium, aortic root, ventricular septum.

LV: left ventricle
LA: left atrium
RV: right ventricle

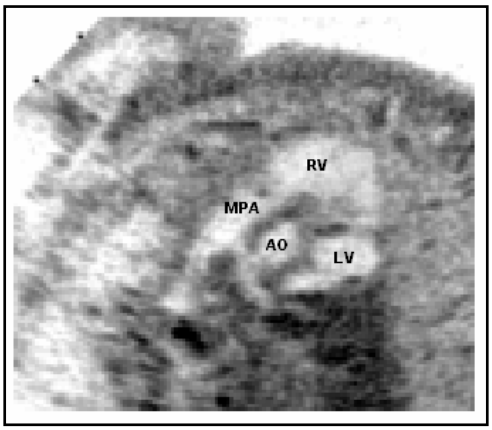


4. Pulmonary Outflow View (RVOT)

Once the aortic outflow tract is identified, the transducer is "rocked" into nearly a straight sagittal plane. This view identifies the main pulmonary artery exiting the right ventricle perpendicular to the ascending aorta. This crisscross relation is the result of normal rotation of the great vessels early in embryogenesis. If the pulmonary artery and aorta are parallel rather than forming this criss-cross, there is a rotational abnormality of the great vessel, most commonly transposition of the great vessels.

RVOT: Demonstrates aorta in cross section with main pulmonary artery lying anterior to aorta. Right ventricle also seen.

RV: right ventricle
LV: left ventricle
MPA: main pulmonary artery (pulmonary trunk)
AO: aorta



5. Short Axis View

With the fetus in the supine position, the short axis of the outflow tracts can be identified by directing the transducer parallel to the spine and moving to the left side of the fetus. In this view, a circular structure is identified (aorta) with a similar-size vessel draping over it (pulmonary artery). Lateral to the aorta, the tricuspid valve leaflets can be observed opening and closing. Within the aorta and the pulmonary artery, movement of the valves can be observed. The pulmonary artery bifurcates near the spine.

6. Other Views

When the apex of the heart is parallel to the transducer beam, the *five-chamber view* of the heart may be identified. This view is obtained by moving slightly more cranial from the four-chamber view of the heart in such a way that the aortic root is identified in the center of the heart. Also, the *longitudinal view* of the aortic arch can be obtained when the transducer is positioned so that a parasagittal scan through a right anterior approach or a left posterior approach can identify the aortic arch and the descending aorta. In this longitudinal view of the aortic arch, the great vessels are identified originating from the aortic arch. A view of the ductus arteriosus entering into the descending aorta can be obtained by moving the transducer slightly from this anatomic plane.

7. Fetal Cardiac Hemodynamics

Blood enters the fetal heart via the conduits into the right atrium. The ductus venosus and the hepatic veins empty into the IVC, which directs blood into the right atrium. The eustachian valve and the crista dividens channel blood through the right atrium toward the foramen ovale and into the left atrium. Blood flow through the heart is proportioned as follows:

a. **40%** right atrial blood→ foramen ovale→ left atrium→ systemic
b. **60%** right atrial blood→ right ventricle. Of this 60%, right ventricular output is as follows:
    i. **92%**→ main pulmonary artery→ ductus arteriosus→ systemic
    ii. **8**%→ right ventricular blood→ pulmonary artery → lungs

8. **Echo Abnormalities**: Fetal echocardiography is useful in diagnosing the following categories of heart abnormalities:
   a. Structural heart abnormalities
   b. Fetal arrhythmias
   c. Assessment of hydrops fetalis
   d. Prediction of hydrops fetalis
   e. Assessment of ductal patency in patients receiving indomethacin
   f. Coarctation of the aorta and other obstructive lesions

9. **Structural Abnormalities include**:
   a. Abnormal positional findings
      i. Diaphragmatic hernia
      ii. Complex congenital heart disease
      iii. Thoracic ectopia cordis (Pentralogy of Cantrell
      iv. Extra - cardiac abnormalities of the thorax
   b. Abnormal cardiac size
      i. Cardiomegaly
      ii. Pulmonary hypoplasia

c. Disproportionate ventricular size
   i. Usually associated with a complex cardiac abnormality
   ii. Coarctation of the aorta
   iii. Unilateral ventricular hypoplasia
   iv. Single ventricle

d. Septal defects
   i. Atrial septal defect (ASD.
   ii. Endocardial cushion defect
   iii. Ventricular septal defect (VSD)

e. Abnormalities of cardiac wall
   i. Cardiomyopathies
   ii. Focal masses (rhabdomyomas)
   iii. Pericardial effusions
   iv. Atrioventricular defect

Cardiac Abnormalities

1. Atrial Septal Defect (ASD)

Any abnormal opening between the atria is referred to as an atrial septal defect. In the newborn, hemodynamic considerations include right to left shunting of blood. Since this pattern is normal in the fetus, ASD is not significant hemodynamically.

a. **Sonographic Findings**:
   i. Relies on demonstration of echo dropout at the level of atrial septum
   ii. Since foramen ovale is normally open, prenatal diagnosis is unlikely

2. Ventricular Septal Defects

Ranks first in frequency of all cardiac anomalies. Caused by incomplete closure of interventricular (IV) foramen and failure of the membranous part of IV septum.

a. **Sonographic Findings:**
   i. Demonstration of an opening between the ventricles
   ii. Larger defects are easier to diagnose

3. Hypoplastic Heart Syndrome

Usually affecting the left side, hypoplastic heart syndrome is a lethal condition. It typically affects the ventricle, the atrium and the aorta. The unaffected side may be enlarged. Fetal hydrops may occur if pulmonary venous return is obstructed.

a. **Sonographic Findings:**
   i. Absent ventricle on 4 chamber view
   ii. Absent or small atrium and aorta

iii.

4. Transposition of the Great Arteries (TGA)

The origins of the great vessels are transposed so that the aorta arises from right ventricle and pulmonary trunk arises from left ventricle.

a. **Sonographic Findings:**
   i. Correct right - left orientation is ESSENTIAL
   ii. Images of outflow tract demonstrates anomalous origin of great arteries
   iii. Difficult sonographic diagnosis

5. Ectopia Cordis

In ectopia cordis, all or part of heart is located outside of chest cavity. It is frequently associated with intracardiac anomalies and omphalocele in Pentalogy of Cantrell.

a. **Sonographic Findings**:
   i. Small thorax
   ii. Extension of soft tissue outside thoracic cavity in which cardiac activity is noted.

6. Other Cardiac Anomalies

Contemporary real-time ultrasound imaging systems allow for complete echocardiographic examination of the fetal heart. Color blood flow mapping and M-mode techniques allow specialists in fetal cardiac imaging to diagnose many problems prenatally. Some other conditions that can be diagnosed using ultrasound include:

a. **Endocardial cushion defects**: atrial or ventricular septal defects resulting from failure of the common AV orifice to separate into mitral and tricuspid valves.
b. **Tetralogy of Fallot**: consists of four anatomic abnormalities: large VSD, overriding aorta, pulmonary infundibular stenosis, right ventricular hypertrophy
c. **Ebstein's anomaly**: downward displacement of the septal and posterior leaflets of the tricuspid valve
d. **Truncus arteriosus**: failure of the aorta and pulmonary artery to form as completely separate vessels. Variations on exact configuration varies.
e. **Ventricular hypertrophy**: in utero hypertrophy is most commonly associated with cardiac outlet obstruction but may be associated with maternal diabetes.
f. **Cardiac tumors**: rare. Most common types are rhabdomyomas and rhabdosarcomas.

Pulmonary Abnormalities

1. Cystic Adenomatoid Malformation Of The Lung (CAML)

Cystic adenomatoid malformation is typically a unilateral condition characterized by the replacement of normal lung parenchyma with cysts. In cases where the lesions are large enough, the mediastinum may be shifted away from midline. Three classes of CAML exist based on the size of the cysts:

Type I	large cysts
Type II	multiple small cysts < 1-2 cm
Type III	non-cystic lesions producing a mediastinum shift

a. **Associated abnormalities** include:
   i. Non-immune hydrops fetalis
   ii. Polyhydramnios
   iii. Bilateral renal agenesis
   iv. Hydrocephalus
   v. Cardiac anomalies

b. **Sonographic Findings:**
   i. Demonstration of a nonpulsatile cystic mass in the fetal lung
   ii. Lateral displacement of the heart (Figure III.I)
   iii. Sonographic signs of hydrops fetalis
   iv. Polyhydramnios

2. **Pulmonary Sequestration**

The separation of a mass of pulmonary parenchyma from the normal lung results in pulmonary sequestration. This "mass" receives it blood supply from the systemic circulation and does not communicate with the bronchial tree. Non-immune hydrops may be present.

a. **Sonographic Findings**
   i. Echogenic, intrathoracic mass
   ii. Sonographic signs of hydrops fetalis