Sonographic Screening Examination of the Fetal Heart

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Disclosures

Lami Yeo, MD
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Learning Objectives

- After completing this presentation, the learner will be able to:

1. Learn why it is important to perform a sonographic screening examination of the fetal heart
2. Establish fetal situs, cardiac axis, and position
3. Recognize normal fetal cardiac structures on ultrasound
4. Determine which fetal cardiac views should be obtained during a sonographic screening exam

Outline

Sonographic screening examination of the fetal heart
- I. Introduction
- II. Congenital heart disease
- III. General considerations
- IV. Fetal cardiac examination
  - A. Four-chamber view
    - 1. Establishing situs
    - 2. Establish cardiac axis and position
  - B. Normal cardiac structures
  - C. Outflow tracts
    - 1. Aorta
    - 2. Pulmonary artery
    - 3. Short axis view of great vessels
  - D. Three-vessel and three vessels and trachea views
  - E. Color flow Doppler

Introduction

Why is it important to learn how to perform a sonographic screening examination of the fetal heart ?

Introduction

- The <u>purpose</u> of sonographic screening examinations of the fetal heart is to maximize the detection of cardiac abnormalities during a second trimester ultrasound
- Performed in low-risk fetuses that are examined as part of routine prenatal care
- Specific cardiac views are recommended

Lee W. J Ultrasound Med 1998; 17:601-607
AIUM Practice Parameter for the Performance of Obstetric Ultrasound Examinations 2013

Introduction

- Suspected congenital heart defects will require a more comprehensive evaluation using fetal echocardiography

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Congenital Heart Disease

Incidence: 4 – 13 per 1000 live births

- Leading cause of infant mortality
- Between 1950 – 1994, 42% of infant deaths reported to the World Health Organization (WHO) were attributable to cardiac defects

Cuneo BF et al. J Perinatol 2004; 24:674-678
Meberg A et al. Acta Paediatr 2000; 89:1344-1351
Ferencz C et al. Am J Epidemiol 1985; 121:31-36
Rosano A et al. J Epidemiol Community Health 2000; 54:660-666

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Congenital Heart Disease

- Structural cardiac anomalies are among the most frequently missed abnormalities during prenatal sonography
- Important cause of medico-legal liability
- High proportion of cases of congenital heart disease detectable prenatally occurs in patients without risk factors or extracardiac anomalies (thus, the importance of fetal cardiac screening)

Crane JP et al. Am J Obstet Gynecol 1994; 171:392-399
Abu-Harb M et al. Arch Dis Child 1994; 71:3-7
Stumpflen I et al. Lancet 1996; 348:854-857

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Congenital Heart Disease

- Prenatal detection of congenital heart disease may improve the outcome of fetuses with specific types of cardiac lesions:
  - Transposition of great vessels
  - Hypoplastic left heart syndrome
  - Coarctation of aorta

Bonnet D et al. Circulation 1999; 99:916-918
Tworetzky W et al. Circulation 2001; 103:1269-1273
Andrews R et al. Arch Dis Child 2001; 85:474-477
Franklin O et al. Heart 2002; 87:67-69
Tworetzky W et al. Circulation 2004; 110:2125-2131

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Important Reasons to Identify Congenital Heart Defects *In-Utero*

- Prenatal counseling
- Invasive testing to detect aneuploidy
- Pregnancy options
- Delivery at an appropriate facility
- Optimal obstetrical and neonatal care

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General Considerations

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General Considerations

- Ultrasound examination optimally performed at 18 – 22 gestational weeks
- Some cardiac lesions are detected later in gestation (e.g. coarctation of aorta)
- Use the highest possible transducer frequency
- Use the cine-loop feature (e.g. confirm movement of valve leaflets)

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General Considerations

- High frame rate
- Increased contrast
- Single acoustic focal zone
- Relatively narrow image field
- Magnify the image

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Fetal Cardiac Examination

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Four-Chamber View

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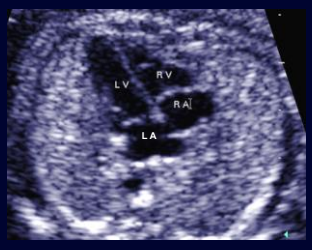
Four-Chamber View



- There are 4 normal cardiac chambers (right and left atrium, right and left ventricle)

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Establishing Situs

- Establish fetal position (vertex, breech, transverse)
- Identify the fetal right and left sides
- Identify that both fetal stomach and heart are on the left side of the fetus

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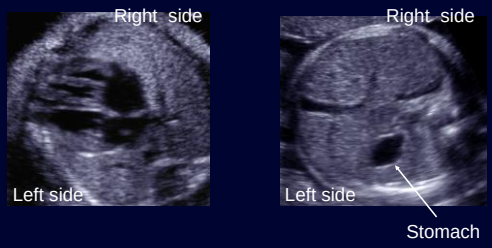
Establishing Situs



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Types of Situs

- Situs solitus (normal)
  - Liver on right
  - Stomach, apex of heart, aortic arch on left
- Situs inversus (“mirror image”)
  - Liver on left
  - Stomach on right
- In either situs solitus or inversus, the cardiac apex may point to the left (levocardia), or point to the right (dextrocardia)

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Situs Ambiguous

- Neither situs solitus or inversus (indeterminate situs)
- Also known as cardiosplenic syndromes, or heterotaxy
- Two most common forms are:
  - Polysplenia or asplenia syndromes
- Some organs are on the correct side, while others are on the opposite of the expected side

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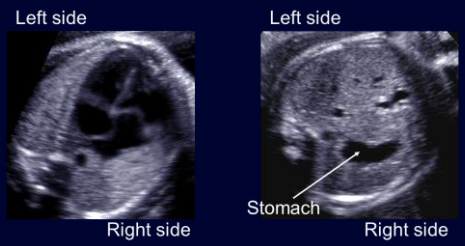
Situs Ambiguous



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Establish Cardiac Axis and Position

- Normal orientation is called levocardia
- Heart size occupies one-third of the chest area
- Cardiac apex points to the left, and the majority of the heart occupies the left side of chest

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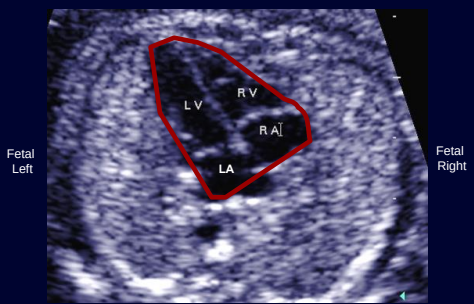
Normal Heart Size



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Establish Cardiac Axis and Position

- Angle of fetal heart relative to the midline should be 45 ± 20 degrees
- Left atrium is closest to the fetal spine
- Right ventricle is closest to the anterior chest wall

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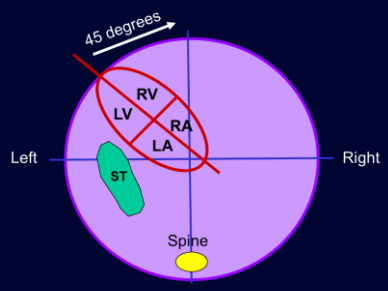
Normal Cardiac Axis and Position



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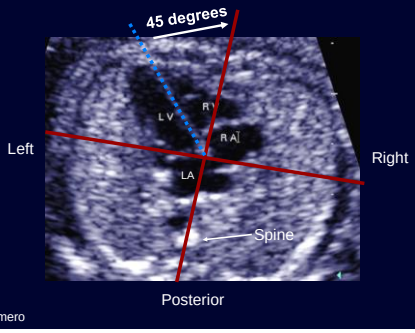
Comstock C. Obstet Gynecol 1987; 70:255-259

Normal Cardiac Axis and Position



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Cardiac Malposition

- Abnormal cardiac axis
  - Often associated with intrinsic complex cardiac defects and dysrhythmias
- Abnormal cardiac position or displacement of heart
  - Due to extracardiac defect

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Cardiac Malposition

- Dextrocardia
  - Heart located in right side of chest, apex points to the right
- Mesocardia
  - Heart located in midchest, apex points to the midline
- Dextroposition
  - Pathologic displacement of heart into right thorax, apex points to the left
  - Extracardiac malformations (e.g. diaphragmatic hernia)

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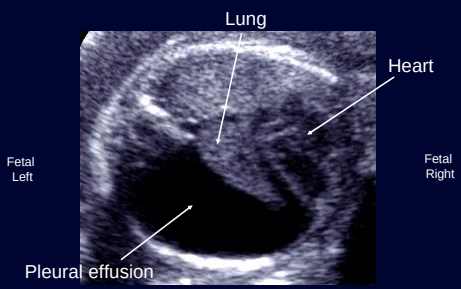
Dextroposition



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Normal Cardiac Structures

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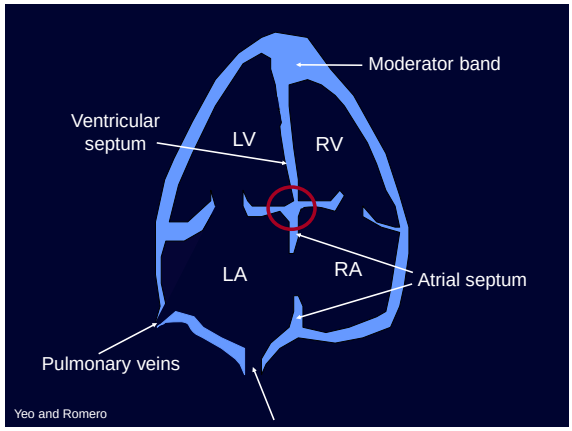

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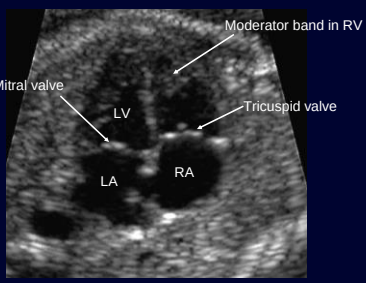
Four-Chamber Apical View



Apex of heart points directly towards / away from the transducer

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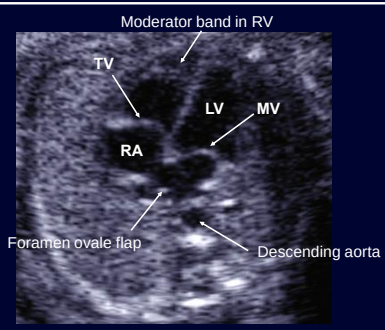
Four-Chamber Apical View



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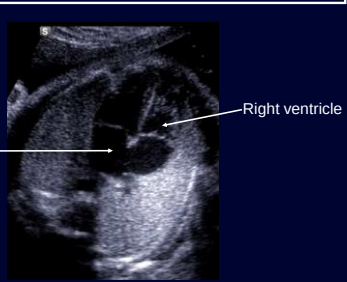
Four-Chamber Apical View



Apex of heart points directly towards / away from the transducer

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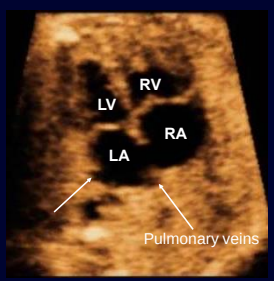
Cardiac Atria

- Two atria similar in size
- Left atrium
  - Foramen ovale flap
  - Irregular posterior borders due to pulmonary veins
- Right atrium
  - Smooth borders
  - SVC and IVC enter this chamber



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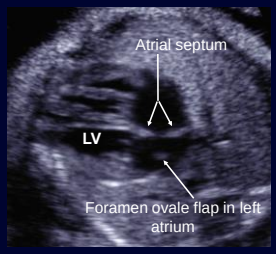
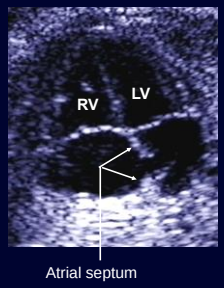
Atrial Septum





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Foramen Ovale

- Umbilical venous blood entering the inferior vena cava preferentially streams towards the left side of the heart, through the foramen ovale
- Left atrial blood enters left ventricle, and then the ascending aorta
  - Most of this blood supplies the head and upper extremities of the fetus (via vessels from aortic arch)
  - Rest of the blood continues down the descending aorta

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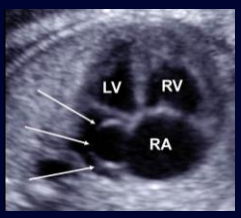
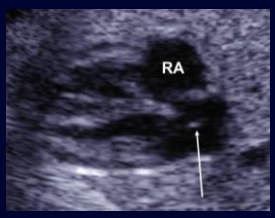
Foramen Ovale





- Located in middle one-third of atrial septum
- Flap is located in the left atrium

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Cardiac Ventricles

- Two ventricles are approximately equal in size
  - In late pregnancy, the right ventricle is slightly larger than the left ventricle
- Right ventricle
  - Coarse trabeculation
  - Moderator band at apex (looks “shorter” than left ventricle)
- Left ventricle
  - Smooth contours
  - Conical shape
  - Forms the apex of the heart

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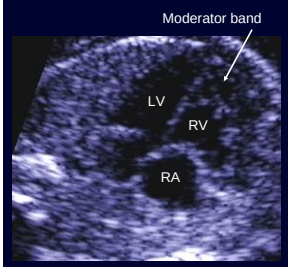
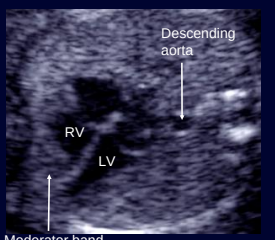
Cardiac Ventricles





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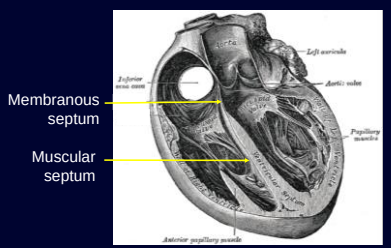
Interventricular Septum



- Thickest at apex
- Narrows to become thinnest at level of atrioventricular valves

https://en.wikipedia.org/wiki/Interventricular_septum#/media/File:Gray498.png

Interventricular Septum

- Should be intact from the apex of the heart to the crux
- Muscular septum (mostly)
- Membranous septum (thin, near atrioventricular valves)

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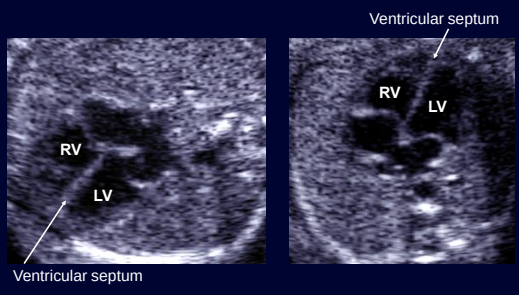
Interventricular Septum



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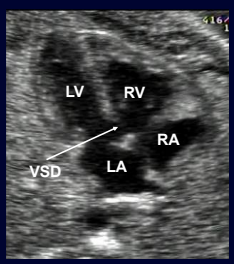
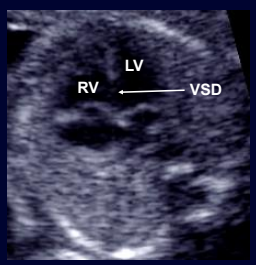
Ventricular Septal Defects





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Atrioventricular Valves

- Two distinct valves (versus one common valve)
- Mitral, tricuspid valves
  - Always follow the respective ventricles
  - Both valves open separately and move freely
  - Two sets of "clapping hands"
  - Both valves should be the same size

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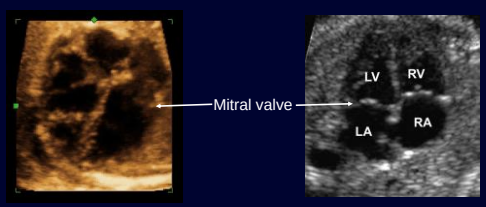
Atrioventricular Valves



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Atrioventricular Valves

- Mitral, tricuspid valves
  - Septal leaflet of tricuspid valve inserts on ventricular septum closer to the cardiac apex (more "apically") than the mitral valve
  - Valves should never be at the same level
  - "Sea-gull wing" appearance (valves are normally off-set)
  - Mitral valve has attachments to the lateral wall left ventricle
  - Mitral valve has 2 leaflets, and tricuspid valve has 3 leaflets

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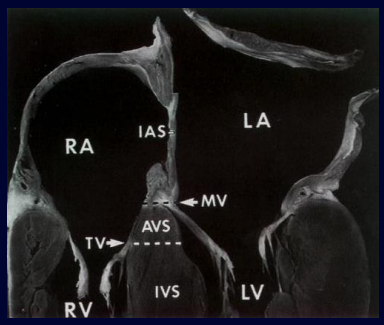
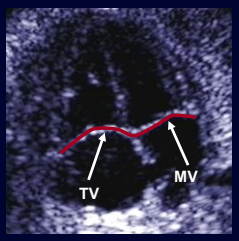
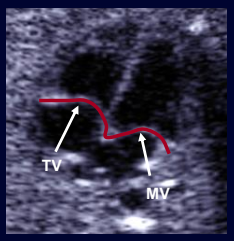


Allen HD et al. Moss and Adams' Heart Disease in Infants, Children, and Adolescents: Including the Fetus and Young Adult, 2000

"Sea-gull Wing" Appearance Valves





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Outflow Tracts: Aorta and Pulmonary Artery

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Why is Evaluation of Outflow Tract Views Important?

- Some cardiac defects (e.g. transposition of great arteries) may <u>not</u> be evident from the four-chamber view alone (e.g. transposition of great vessels)
- Complementing the four-chamber view with the outflow tract views in cardiac screening is important to improve the prenatal detection of congenital heart disease

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Outflow Tract Views

- Integral part of fetal cardiac screening
- Great vessels are approximately equal in size and <u>cross each other</u> at right angles from their origins as they <u>exit from the ventricles</u>

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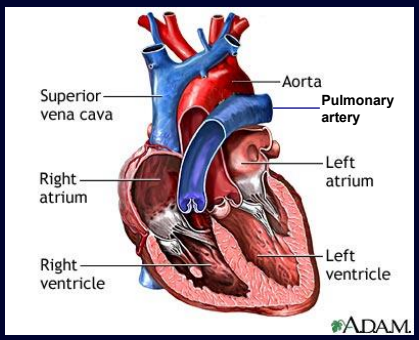
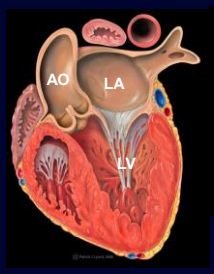
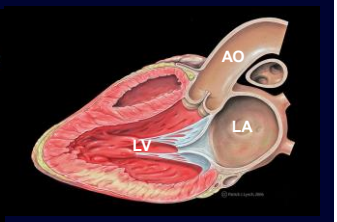


http://static.howstuffworks.com/gif/adam/images/en/heart-chambers-picture.jpg

Aorta





Aorta arises from the left ventricle

http://commons.wikimedia.org/wiki/File:Heart_left_ventricular_outflow_track.jpg
http://commons.wikimedia.org/wiki/File:Heart_inferior_lv_wall_dysfunction.jpg

Long Axis View of Aorta

- Aorta is identified by head vessels arising from the aortic arch
- Continuity of anterior wall aorta with ventricular septum
- Continuity of posterior wall aorta with mitral valve
- Aortic valve should move freely and is not thickened

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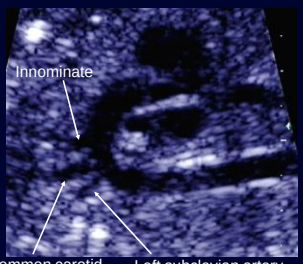
Head Vessels Arising from Aortic Arch



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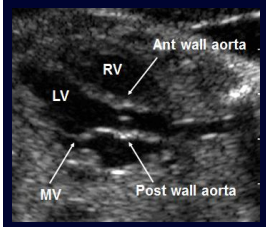
Long Axis View of Aorta



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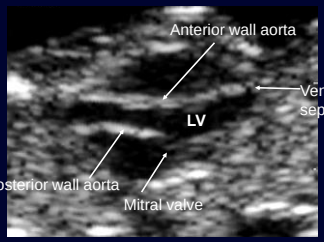
Long Axis View of Aorta



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Long Axis View of Pulmonary Artery

- Pulmonary artery arises from right ventricle
- Pulmonary artery should cross the aorta, and is anterior to the aorta
- Pulmonic valve should move freely and is not thickened
- Can measure the pulmonary annulus
  - Slightly larger than the aortic root in fetal life

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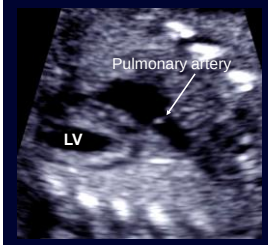
Long Axis View of Pulmonary Artery



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Short Axis View of Great Vessels

- Aorta appears as circular structure, with pulmonary artery coursing over it
- Pulmonary artery bifurcates
  - Ductus arteriosus and right pulmonary artery
- Can visualize aortic, pulmonary, tricuspid valves
- Can compare aortic and pulmonary annulus

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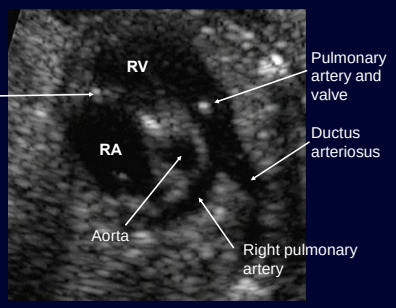
Short Axis View of Great Vessels



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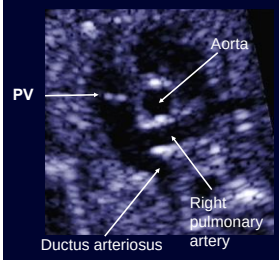
Short Axis View of Great Vessels



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Three-vessel view (3VV) and Three vessels and trachea view (3VT)

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3VV and 3VT

- Visualization of these views is desirable and should be attempted as part of the routine fetal cardiac screening examination
- Both planes define three vascular structures, and their relationships with each other and with the trachea

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Three-Vessel View (3VV)

- From left to right, the vessels are:
  - Pulmonary artery, aorta, SVC
- Assessment of vessel number, size, alignment, and arrangement can be made
- Pulmonary artery is most anterior vessel; SVC is most posterior
- Relative diameters decrease from left to right (pulmonary artery larger than aorta, and aorta larger than SVC)

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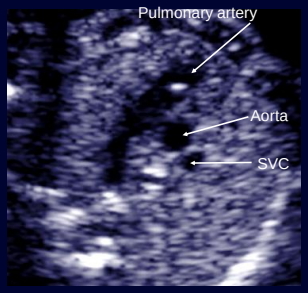
Three-Vessel View (3VV)



- Certain congenital heart defects associated with a normal four-chamber view are likely to have an abnormal 3VV
  - Examples: tetralogy of Fallot, transposition of great vessels

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Three Vessels and Trachea View (3VT)

- More cephalad image
- Transverse aortic arch is better visualized, and its relationship with the trachea is emphasized
- Both ductal and aortic arches are positioned to left of trachea and form a “V” shape as they both join the descending aorta
- 3VT view allows detection of coarctation of aorta, right aortic arch, etc.

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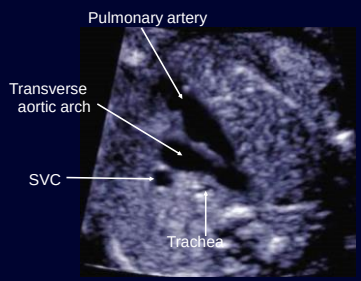
Three Vessels and Trachea View (3VT)



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3VV and 3VT

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Color Flow Doppler

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Color Flow Doppler

- Although this is not mandatory, becoming familiar with its use and adding this to routine screening is encouraged
- Facilitates imaging of cardiac structures and abnormal blood flow patterns
- Plays an important role in diagnosing congenital heart defects

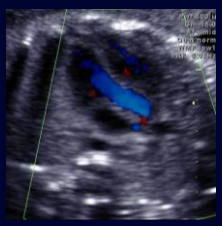
Chaoui R, McEwing R. Ultrasound Obstet Gynecol 2003; 21:81-93
Carvalho JS et al. Ultrasound Obstet Gynecol 2013; 41:348-359

Color Flow Doppler

- Optimal color Doppler settings include:
  - Narrow region of interest
  - Appropriate pulse repetition frequency
  - Low color persistence
  - Adequate gain settings to display flow across valves and vessels

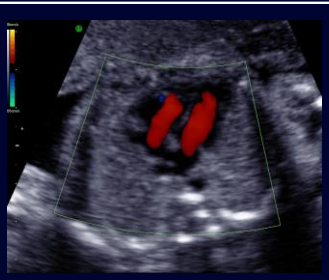
Color Flow Doppler

Diastole (atrioventricular valves)



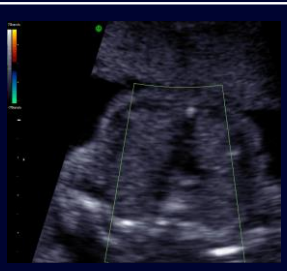
Systole (aorta)

Color Flow Doppler



Color flow through atrioventricular valves (red color) and aorta (blue color)

Color Flow Doppler



Color flow through 3VV and 3VT views

Summary of Identification of Fetal Cardiac Structures

Identification of Cardiac Structures

- Right Atrium
  - SVC and IVC enter this chamber
  - Walls are smooth
- Left Atrium
  - Foramen ovale flap
  - Pulmonary veins drain into this chamber
  - Irregular posterior borders

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Identification of Cardiac Structures

- Right Ventricle
  - Moderator band
  - Trabeculated lining
  - Always associated with respective tricuspid valve
- Left Ventricle
  - Conical shape, apex-forming
  - Smooth lining
  - Always associated with respective mitral valve

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Identification of Cardiac Structures

- Interventricular Septum
  - Mostly muscular
  - Thin, membranous portion near atrioventricular valves

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Identification of Cardiac Structures

- Tricuspid Valve
  - Three leaflets (anterior, posterior, septal)
  - Septal leaflet attachments
  - Has a more apical insertion on ventricular septum (vs. mitral valve)
- Mitral Valve
  - Two leaflets (anterior, posterior)
  - Attachments to lateral wall left ventricle

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Identification of Cardiac Structures

- Pulmonary Artery
  - Must bifurcate
- Aorta
  - Must have head vessels

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Conclusions

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Conclusions

- There are many important reasons to identify cardiac defects *in-utero*
- When imaging the fetal heart on ultrasound, recommend optimizing the image size and quality
- An abnormal cardiac axis and/or position may be associated with cardiac or extracardiac defects

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Conclusions

- It is important to establish situs (situs solitus is normal)
- Examination of the four-chamber view of the heart is more than just counting four cardiac chambers
- The foramen ovale flap is located in the left atrium

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Conclusions

- The right ventricle is identified by the moderator band
- Mitral and tricuspid valves always follow their respective ventricles (even if there are cardiac anomalies)
- Mitral and tricuspid valves should never be at the same level, and are normally off-set
  - Tricuspid valve has a more apical insertion on ventricular septum than the mitral valve

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Conclusions

- Evaluation of the outflow tracts is important because:
  - It can increase detection rates for major cardiac defects
  - Some cardiac abnormalities may not be evident from scanning the four-chamber view alone

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Conclusions

- Aorta is identified by 3 head vessels arising from the aortic arch
- Great vessels should cross as they exit their respective ventricles
- Pulmonary artery is identified by its bifurcation into the ductus arteriosus and right pulmonary artery

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Key References

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AIUM Practice Parameter for the Performance of Obstetric Ultrasound Examinations; 2013 and renamed 2015

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Thank You

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