A Review of Fetal Circulation and the Segmental Approach in Fetal Echocardiography

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The incidence of congenital heart disease is generally estimated at 8 in 1000 live births. Fifty percent of these neonates will have "minor" defects—easily corrected with some intervention. The remainder will account for 30% of perinatal deaths and nearly 50% of lethal malformations in childhood. The purpose of this review is to outline essential guidelines for a thorough fetal echocardiogram and how it differs from the fetal cardiac imaging included as part of an obstetric sonographic examination. Specific values for both the anatomic and blood flow velocity measurements recommended are typically related to gestational age and method of acquisition. Multiple references exist in the literature that define these values.

Key words: obstetrical fetal heart, fetal echocardiography, fetal circulation

Congenital heart disease (CHD) occurs 6.5 times more frequently than chromosomal abnormalities and 4 times more frequently than neural tube defects.[1] Many congenital heart defects may be missed without the routine inclusion of cardiac screening in the obstetrical sonographic protocol.[2,3] When a congenital heart defect is diagnosed in utero, a team approach involving the obstetrician, the perinatologist, the pediatric cardiologist, the pediatric surgeon, the parents, and other specialists as needed allows for a much more positive, more controlled outcome. This is especially true for those families residing far away from tertiary care centers and for whom delivery must be planned at a high-risk facility capable of providing the necessary surgical treatment and medical support of the neonate.

Fetal Circulation

Core to examining the fetal heart is understanding fetal circulation and its effects. The flowchart

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provided (Fig. 1) diagramatically presents the following:

- Fetal circulation occurs in parallel rather than in series.
- The majority of the cardiac output from the right ventricle is to the placenta and the lower half of the body.
- The majority of the cardiac output from the left ventricle is to the heart, brain, and upper body.
- The mixing of blood that occurs at the atrial level (through the foramen ovale) and between the great vessels (via the ductus arteriosus) diverts blood from the immature lungs to the placenta for oxygenation.
- The placenta is not as efficient as the lungs in providing oxygenation. Therefore, the oxygen content of fetal blood is considerably lower than that of a neonate or child. Blood with the highest O_2 content is diverted to the coronary arteries and brain, whereas the blood with the lowest O_2 content is directed to the placenta to increase the efficiency of oxygen pickup.[4]

EFFECTS OF FETAL CIRCULATION

- Parallel circulation with mixing at atrial and great vessel levels allows a wide variety of cardiac malformations to be present while still maintaining adequate flow to the placenta for oxygen exchange and distribution (Fig. 2).
- The right ventricle performs nearly two thirds of the heart's work in utero, thus contributing to its slightly larger size and thickness as well as an increased amount of flow through the pulmonary artery relative to the aorta.[5]
- Pulmonary flow in the fetus is very small in comparison to the neonate. Due to their size, normal pulmonary veins are difficult to image and are typically best defined by color flow Doppler imaging. Anomalies that would prevent normal pulmonary return (e.g., mitral stenosis and total anomalous pulmonary venous connection) may be masked in the fetus as the pulmonary return is already low, which further increases the difficulty in defining these vessels and their connections.
- Normal flow across the aortic isthmus (the section of the aorta between the left subclavian artery and the ductus arteriosus) is small—only 10% of the total cardiac output. Therefore, the isthmus is very vulnerable to changes in flow that may be produced by congenital heart defects. This may contribute to narrowing (coarctation) or interruption of the arch at this level of the aorta.

Consideration of Bioeffects

Prior to examining the fetus, it is important to remember that no known permanent injury has ever been documented using current commercial instrumentation. A threshold for bioeffects has yet to be determined; the responsible approach is to control total exposure to the patient by controlling output level and exposure time.

- Maximize the balance between a good (diagnostic) image and reduced output power levels by fully using receiver controls. Receiver gain, time gain compensation (TGC), postprocessing, and dynamic range have no effect on output.
- Minimize the use of both spectral and color flow Doppler imaging.
- Limit the actual exposure time whenever possible—for example, removing the probe from the maternal abdomen when not actually imaging (i.e., when performing measurements or annotating an imaging).

The Extended Fetal Cardiac Screen

This section provides the essential elements of the obstetric sonographer's cardiac screen. It is termed *extended* because it requires imaging beyond the four-chamber view of the heart required by American Institute of Ultrasound in Medicine guidelines.[6] The extended screen is composed of the four-chamber view, the left ventricular outflow tract (LVOT), the right ventricular outflow tract (RVOT), and the main pulmonary artery (PA) and its branches. In a study of 5400 fetuses in low-risk pregnancies, Achiron and colleagues[6] compared the standard four-chamber view with the extended fetal cardiac screen in detecting abnormalities.

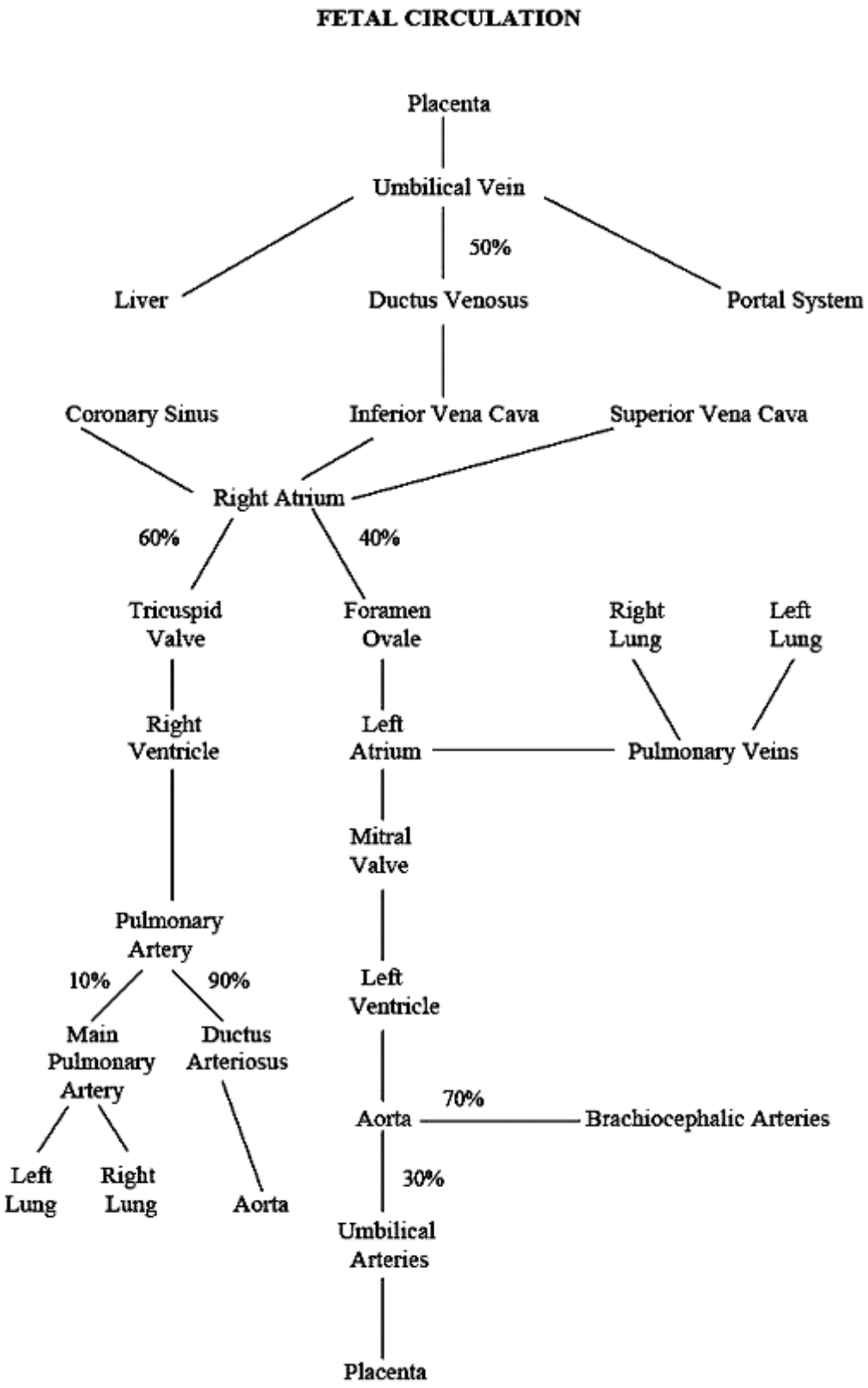

FIG. 1. Fetal circulation.

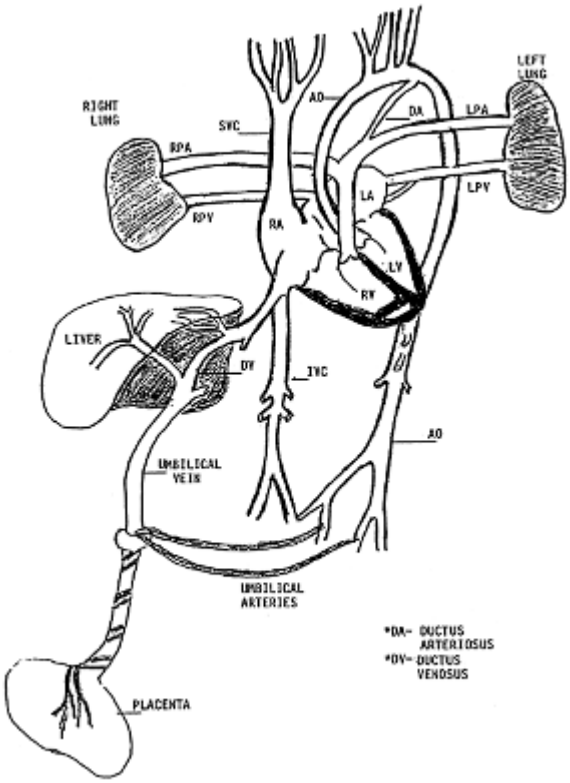

FIG. 2. Ladder diagram of fetal circulation.

Sensitivity increased from 48% with the four-chamber view alone to 78% with the addition of the outflow tracts and pulmonary artery imaging in pregnancies between 18 and 24 weeks' gestation. This sensitivity translated to an 86% detection rate of the cardiac abnormalities, confirmed by neonatal echocardiography or postmortum examination. Considering the size and unbiased nature of the population examined, this study not only demonstrates the need for the more comprehensive screen but also the impact that can be made on fetal management by routinely including these views in an obstetric sonographic protocol.

TIMING OF EXAMINATION

Initial imaging of cardiac structures is usually performed between 18 and 24 weeks of gestation but may be performed any time up to term. Fetal heart size, fetal position, and body size contribute to adequate visualization and evaluation of cardiac structures and function. A study by Yagel and colleagues[7] suggests that although most fetal cardiac anomalies are detectable in early or mid-gestation, some may vary in appearance at different stages of fetal development and may evolve in utero during the entire course of pregnancy. As a result of their findings, these authors speculate that an early or mid-gestation cardiac evaluation followed by a late second- or third-trimester study may increase the detection rate of congenital heart disease. This consideration of in utero evolution of cardiac anomalies was addressed by Snider and associates,[3] citing numerous references concerning the progression of forward flow-related lesions throughout gestation.

DETERMINATION OF SITUS

The first step in the determination of situs is to determine fetal position and presentation. This step should be performed immediately prior to cardiac imaging. Once fetal lie is determined, a cross section of the fetal abdomen at the level of the stomach bubble should be obtained to assess visceral situs as well as the position of the great vessels relative to the spine. Once this is done, cardiac imaging may begin by simply moving the transducer above the diaphragm while still imaging in a transverse cross section.

CARDIAC IMAGING

Because the lungs are not inflated in utero, the fetal heart lies more horizontal than the neonatal heart and may be imaged in planes not possible after birth when air and bone become a barrier to sound transmission. In late gestation, the spine and ribs become more ossified and therefore more of a hindrance to imaging cardiac structures. The following should be determined from a four-chamber view:

- Position of the heart within the chest (i.e., levocardia vs. dextrocardia vs. mesocardia).
- Position of apex relative to the base of the heart (i.e., levoversion vs. dextroversion).
- Verification of four chambers, an intact interventricular septum, an intact intra-atrial septum, and two atrioventricular valves.
- Identification of the characteristics of the morphologic right ventricle to distinguish a morphologic right ventricle from a morphologic left ventricle.

  - The moderator band, also know as the septomarginal trabeculation, is the fibrous band that traverses the apex of the right ventricle.
  - The right ventricle should appear trabeculated as opposed to the smooth-walled left ventricle.
  - The right ventricle should be the chamber closest to the anterior chest wall, and the left atrium should be the chamber closest to the spine.
  - The septal leaflet of the tricuspid valve should insert on the interventricular septum slightly closer to the apex of the heart than the septal leaflet of the mitral valve.
- Proportion of the left ventricle to the right ventricle. Allan et al[1] found that early in pregnancy, the ventricular sizes were fairly equal, with the right becoming slightly more dominant in later gestation due to a higher workload in utero. Measurements of the ventricles are taken at the level of the valves at end diastole, when the atrioventricular valves are closed.
- The foramenal flap should be seen moving within the left atrium.
- The Eustachian valve may be visible within the right atrium. This structure serves to direct the higher O_2 content blood from the inferior vena cava across the foramen ovale into the left heart.

Once an evaluation of structure and function in the four-chamber view is complete, visualization of the outflow tracts may be accomplished by two different methods:

- Cephalad angulation of the transducer from the four-chamber view will allow visualization of the left ventricular outflow tract arising from the morphologic left ventricle (also known as the five-chamber view). Continued cephalad angulation will bring the right ventricular outflow tract into view.

Sometimes, this transition from four chamber to five chamber to right outflow tract is not easily accomplished. Fetal position and angulation of the fetal thorax within the maternal abdomen play roles in this method of acquisition. An alternative method is as follows:

- Short axis at the level of the great vessels. Because the fetal heart lies nearly horizontal in the thorax, this view is obtained by turning the transducer 90 degrees to image the fetus in a sagittal plane—parallel to the fetal spine—at the cardiac base. This view documents the aorta with the aortic valve in cross section while the right outflow tract, pulmonary valve, and pulmonary artery drape lengthwise anterior to the aorta.

The two most important elements to note when evaluating the outflow tracts and the great vessels are the relative position and proportion of these structures to one another.

- Criss-cross relationship. The aorta and pulmonary arteries should cross one another in a normal relationship. If these two vessels lie parallel to one another or are not separately identified, a significant cardiac abnormality may be present (e.g., transposition of the great arteries, double-outlet right ventricle, and truncus arteriosus).
- Proportion of the pulmonary artery to the aorta (the PA/AO ratio). Comstock and colleagues[8] demonstrated that the PA/AO ratio is independent of gestational age, with a normal mean value of 1.09 (range, .75-1.43). Examples of congenital heart defects, which may be indicated by an increased PA/AO, are hypoplastic left heart, double-outlet right ventricle, and coarctation of the aorta. Examples of congenital heart defects, which may decrease the PA/AO ratio, are tricuspid atresia, pulmonary atresia, and tetralogy of Fallot.

Identifying the bifurcation of the pulmonary artery into the right and left main pulmonary arteries verifies that the pulmonary artery is, indeed, the great vessel arising from the right ventricle. Visualization of this relationship is a step toward verifying ventriculoarterial concordance and completes the suggested requirements of a complete fetal cardiac screen.

RECORDINGS

It is recommended that the cardiac imaging portion of the obstetric sonographic examination be either videotaped or digitally captured in multiple loops. The heart is a dynamic structure. A diagnostic evaluation of the function of the fetal cardiac structures cannot be documented by still-frame imaging. In addition, frame-by-frame evaluation of videotaped structures will facilitate documenting these structures, their relationship to other structures, and their function in an active fetus.

The Complete Fetal Echocardiogram: The Segmental Approach

This section describes the segment-by-segment evaluation required of a fetal echocardiographer for a complete cardiac examination.

INDICATIONS FOR FETAL ECHOCARDIOGRAPHY

- Abnormal cardiac screen during an obstetric (OB) sonographic examination. In a study by Allan and colleagues[9] in 1006 cases of congenital heart disease diagnosed prenatally, 72% were referred because of a suspicious OB screen.
- Family history of CHD. Allan and associates[9] found an occurrence rate of 1 in 52 with one previously affected child and 1 in 10 with two previously affected children. Whittemore and colleagues[10] reported a 16% occurrence risk for offspring of patients with CHD. The actual risk for a given fetus is dependent on the type of CHD involved and the parent affected.
- Maternal disease (e.g., diabetes mellitus, connective tissue disorders).
- Teratogen exposure. Examples of these include alcohol, anticonvulsants, lithium, and progesterones.[11]
- Maternal infection (e.g., rubella virus).
- Chromosomal abnormalities. The incidence varies with different chromosomal abnormalities but is generally thought to be between 30% and 50%. Conversely, a fetus that presents with a congenital heart defect is at an approximate 5% (some references cite 13%) risk for a chromosomal abnormality.
- Extracardiac abnormalities. The risk of an associated cardiac abnormality is 25% to 45% when an extracardiac abnormality is detected in the fetus.[12] Actual incidence varies depending on the organ system involved. Examples of findings associated with congenital heart disease include the following:
  - Diaphragmatic hernia
  - Omphalocele
  - Nonimmune hydrops
  - Abnormal amniotic fluid volume
  - Duodenal or esophageal atresia
  - Central nervous system abnormalities
  - Renal anomalies
- Fetal tachycardia, bradycardia, or persistent irregular rhythm on clinical or screening sonographic examination.
- Abnormal fetal growth. Congenital heart disease may present with evidence of intrauterine growth retardation. Doppler examination of arterial and venous flows (as discussed later) is instrumental in following and timing delivery of these fetuses.
- Evidence of fetal distress. Assessment of fetal cardiac size, ventricular function, and the presence or absence of nonimmune hydrops is performed to document intrauterine congestive heart failure or to detect impending failure.[13]

The Segmental Fetal Echocardiogram

A complete fetal echocardiogram consists of a thorough assessment of connections, cardiac function, and hemodynamics. Figure 3 provides typical views in imaging the heart. This is accomplished with the aid of pulsed and color flow Doppler imaging. M-mode may also be useful in the evaluation of chamber size, wall thicknesses, and dysrhythmias.

THE SEGMENTAL APPROACH

- Establish situs
- Four-chamber view
  - Evaluate chamber morphology.
  - Examine the crux of the heart (cross of ventricular and atrial septa with the atrio-

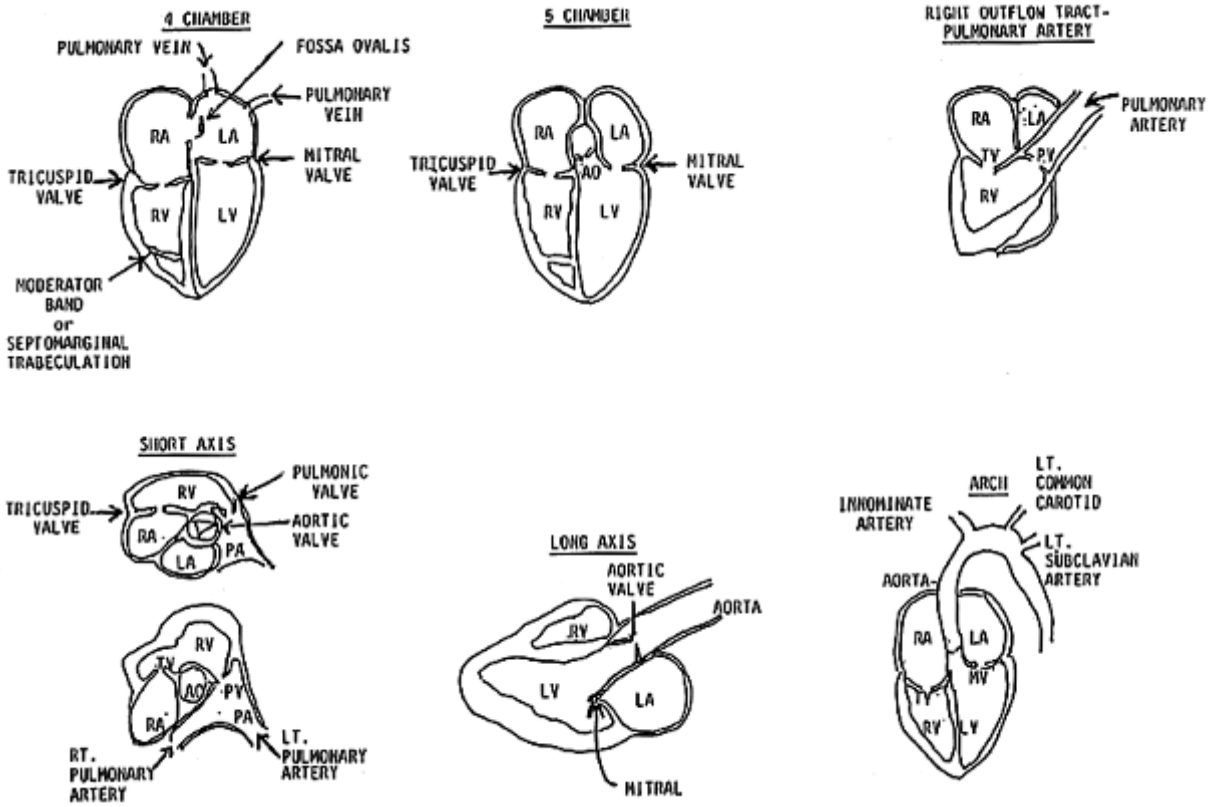

FIG. 3. Diagram of the anatomic elements that contribute to fetal circulation.

ventricular valve insertions) to verify that it is intact.

– Atrioventricular valve insertions. The mitral valve is normally slightly more basally inserted than the tricuspid valve. An abnormally apically displaced tricuspid valve is indicative of Ebstein's anomaly. Identifying valvular insertion is a step toward establishing atrioventricular concordance (or discordance).
– Intact septa. Be alert to the creation of "pseudo" defects (dropout) of the atrial or ventricular septa, which may occur when the angle of insonation is parallel rather than perpendicular to these structures. A subcostal four-chamber view with the beam directed perpendicular to the septa should be employed to aid in the investigation of septal defects.
– Foramen ovale. Note the hemodynamically correct movement of the foramenal flap into the left atrium and evaluate for signs of obstruction. Atrial septal aneurysms or a redundant foramenal flap may also be appreciated in this view and can be associated with rhythm disturbances.
– Color flow Doppler interrogation in a four-chamber view should demonstrate laminar flow through the chambers, with no regurgitant flow from the mitral or tricuspid valves seen within the atria.
– Atrioventricular valve spectral Doppler profiles will be A-wave dominant throughout gestation. The A/E ratio for both valves will tend to decrease with advancing gestational age. For the mitral valve, the decreasing A/E ratio has been shown to be due to an unchanged E velocity and a decreasing A velocity. In the tricuspid valve, an increasing E velocity causes a decreasing A/E ratio.
– Pulmonary veins. Pulsed Doppler and color flow imaging should be used to identify the pulmonary veins. Although very uncommon to demonstrate all four pulmonary veins, at least two can usually be identified by using the

four-chamber view, oblique planes from the four-chamber view, and a high short axis at the base of the heart to rule out total anomalous pulmonary venous connection. Partial anomalous pulmonary venous return is extremely difficult to diagnose in utero.

- Five-chamber view
  - The aorta should be seen arising from the left ventricular outflow tract in this view. Positive identification of the aorta is accomplished by demonstrating the brachiocephalic arteries arising from this vessel.
  - Spectral and color flow Doppler evaluation of the aorta should demonstrate laminar flow. Pulsed Doppler interrogation should be performed proximal to the aortic valve to evaluate for insufficiency and distal to the valve to assess for stenosis.
  - Arrhythmia check. The Doppler sampling gate is placed in the LVOT and opened wide enough to include mitral inflow and LVOT outflow to simultaneously evaluate both the atrial and ventricular components of the cardiac rhythm. The method for interpretation of this spectral display will be discussed later in this section.
  - RVOT/PA. Angulation of the transducer cephalically from the LVOT normally results in visualization of the bifurcating pulmonary artery arising from the RVOT. If unable to image these structures in this plane, a short-axis view of the great vessels should be obtained.
- Short-axis view
  - A short-axis view at the level of great vessels will yield the pulmonary bifurcation and, with some angulation, the ductus arteriosus communicating with the descending aorta.
  - Spectral and color flow evaluation of the pulmonary artery should demonstrate laminar flow. The Doppler sample volume should be placed proximal to the pulmonary valve to evaluate for insufficiency and distal to the valve to evaluate for stenosis.
  - Flow through the ductus arteriosus. Laminar flow should be seen with both spectral Doppler and color flow imaging. Specific characteristics of imaging and velocities will be discussed later.
  - Two separate and distinct atrioventricular valves with nonrestricted leaflets should be identified with continued angulation toward the apex in this cross-sectional plane.
  - A short axis at the level of the ventricles may be used to assess size and contractility. The papillary muscles within the left ventricle may be identified in this plane, distinguishing the left ventricle from the right ventricle.
- Long-axis view
  - Fibrous continuity of the anterior mitral leaflet with the posterior aortic root should be seen.
  - The ventricular septum can be evaluated with color flow Doppler in this view to rule out ventricular septal defects.
- M-mode through the aorta and left atrium to evaluate cardiac rhythm. An M-mode cursor can be placed through the left atrial wall and the aortic root in either a short-axis or long-axis view for a simultaneous demonstration of these structures during the cardiac cycle. The atrial wall motion will reflect atrial rhythm, whereas the opening and closure of the aortic valve will reflect ventricular rhythm.[2]
- Parasagittal views
  - Right atrial inflow. With some slight angulation, a parasagittal plane through the right atrium (RA) should demonstrate both venous connections (inferior vena cava [IVC] and superior vena cava [SVC]) to the right atrial chamber. The Eustachian valve may be appreciated in this plane as well.
  - Aortic arch
    - The aortic arch normally appears as a "candy cane"–shaped structure arising from the LVOT, giving rise to the brachiocephalic arteries.
    - If orientation or acquisition is difficult, start in a long axis of the spine and then angle leftward (fetus) to the descending aorta and trace cranially and oblique slightly leftward for the arch.
    - Pulsed-wave and color flow Doppler should be used to demonstrate laminar, antegrade flow. Retrograde flow would indicate a ductal dependent lesion (i.e., LVOT or AO obstruction).
    - Pay particular attention to the size of the arch, especially at the level of the isthmus, for possible signs of coarctation. Color flow may be particularly helpful in identifying this lesion, but it often goes undetected prenatally, particularly in

mild cases when echocardiographic evidence may be subtle.

– Ductal arch
  - The ductal arch is formed by the communication of the ductus arteriosus with the descending AO and has a characteristic "hockey stick" appearance. That is, it appears more flattened than the aortic arch and will have no head and neck vessels arising from it.
  - It is found in a parasagittal section just leftward of the AO arch.
  - Note laminar flow, direction, and velocity with color flow and spectral (pulsed-wave) Doppler. Normal ductal velocities in 20- to 39-week fetuses range from 50 to 140 cm/sec in peak systole and 6 to 30 cm/sec in peak diastole.[14]
  - Premature ductal constriction is distinguished by its high peak systolic and end-diastolic velocities or absence of flow in premature closure.[15] Although this may occur naturally, this abnormality has been shown to be induced by prostaglandin therapy for premature labor. Severe constriction leads to progressive right ventricular pressure overload, hydrops, and fetal death.
  - Retrograde flow in the ductus arteriosus should prompt investigation for an RVOT or PA obstruction.

- Fetal growth assessment. As stated previously, congenital heart disease may present with evidence of fetal growth retardation. Fetuses with chronic hypoxia as a result of decreased cardiac function often develop intrauterine growth retardation. A study by Hecher and associates[13] demonstrated the significance in evaluating fetal arterial and venous waveforms for evidence of fetal compromise and timing of delivery.
  – Umbilical artery
    - Abramowicz and colleagues[16] suggest that the most accurate measurements are obtained at the placental insertion of the umbilical cord.
    - Systolic peak velocity/end-diastolic velocity ratio (S/D ratio). A normal S/D ratio decreases with advancing gestational age as the vascular cross-sectional area of the placenta increases. A higher ratio reflects increasing vascular resistance of the placental bed. That is, decreased or absent diastolic flow velocities are evidence of fetal compromise.
  – Umbilical vein and inferior vena cava. Pulsations observed in the umbilical vein and a decrease or absence of diastolic flow and increased reversed flow with atrial contraction in the inferior vena cava have been shown to reflect alterations in cardiac function and congestive heart failure in the severely compromised fetus.[17]
  – Ductus venosus
    - The ductus venosus is the venous connection between the umbilical vein and the inferior vena cava.
    - The ductus is found in a transverse section just below the diaphragm or in a longitudinal section through the upper abdomen.
    - The Doppler flow pattern will demonstrate a high S/D ratio in a compromised fetus as well as absent or reversed flow with atrial contraction.
  – Middle cerebral artery/thoracic aorta flow comparison. A comparison of these waveforms is used to evaluate for arterial blood flow redistribution to the cerebral circulation brought about by alterations in vascular resistance in a compromised fetus. An abnormal comparison is characterized by increased diastolic velocities and an overall increase in flow in the cerebral circulation, whereas the thoracic aorta waveform demonstrates a decrease or absence of diastolic velocities and an overall reduction in flow. This compensatory mechanism allows for maximal oxygen delivery to the heart and brain in fetuses with chronic hypoxia.

- Dysrhythmia documentation
  – Echocardiographic methods for cardiac rhythm evaluation.
  – M-mode. A cursor is placed through either the aorta and left atrium or the mitral valve and ventricular walls to simultaneously demonstrate the onset of atrial and ventricular contraction. Atrial systole is determined by the onset of atrial wall motion or the onset of the A wave of the atrioventricular valve. Ventricular systole is determined by the onset of septal or ventricular wall thickening, the opening of the semilunar valve, or the closure of the atrioventricular valve. Atrial and ventricular rates as well as the A-V conduction sequences may be evaluated by this method.

  - Spectral Doppler. A pulsed-wave sample volume is opened to simultaneously include flows through an atrioventricular and semilunar valve, usually the mitral and aortic valves. The onset of the A wave signals atrial contraction, and the opening of the semilunar valve signals ventricular contraction. The ventricular rate and the A-V conduction sequence may be determined by this method. Snider and associates[3] describe employing pulsed-wave Doppler sampling at the left atrial side of the foramen ovale or at the ventricular side of the atrioventricular valve to record flow velocity through the atrioventricular valve in late diastole to determine the atrial rate.
  - Silverman[2] and Snider et al[3] demonstrated the use of ladder diagrams to map cardiac rate and rhythm disturbances.
- Cardiac rates. The normal fetal heart rate decreases gradually from 140 ± 20 beats per minute for a fetus at 20 weeks' gestation to 130 ± 20 beats per minute at term. Abnormal fetal cardiac rhythms are defined in the literature as follows:
  - Sustained bradycardia—less than 100 beats per minute and lasting longer than 10 seconds.
  - Sustained tachycardia—greater than 180 beats per minute and lasting longer than 10 seconds.
  - Frequent irregular beats that occur more often than 1 in 10 beats.

The most common cause of fetal dysrhythmias are the irregular rhythms caused by ectopic beats—most frequently, premature atrial contractions. Ectopic beats in the fetus are generally benign and are only occasionally associated with structural heart disease. Fetuses with normal cardiac anatomy may be followed by the primary physician for fetal heart rate determinations. Mothers are advised to be aware of fetal movement and abstain from smoking, consuming caffeine, and consuming pharmacologically active substances. Silverman[2] found that, in most fetuses, premature atrial or ventricular beats do not persist into the neonatal period.

Transient bradycardias are often found to be benign and are usually associated with fetal movements from mid second trimester to term. They tend to occur less frequently as the pregnancy progresses. Transient bradycardia may be precipitated by applying pressure to the maternal abdomen, such as with an ultrasound transducer. Normal rhythm returns shortly after the probe is removed or applied with less pressure.

A serious cause of prolonged bradycardia is complete heart block. This is diagnosed when the atrial contraction rate is completely unrelated to the ventricular contraction rate. As an isolated lesion, it is usually associated with maternal collagen disease, and mothers should be tested for anti-Ro or anti-La antibodies. When complete heart block is associated with structural heart disease, the outcome depends on the complexity of the lesion, but it is usually related to a high mortality. Prenatal treatment of complete heart block, either medically or with attempted pacemaker implantation, has been disappointing; therefore, early delivery is often indicated in these fetuses when there is evidence of fetal distress.

Prolonged tachyarrhythmias present more frequently than sustained bradycardia in utero and are usually supraventricular in origin. Ventricular tachycardias are less common and may be difficult to diagnose. Tachyarrhythmias usually present as an isolated lesion, but they may be associated with anatomic and functional abnormalities. The method of treatment will be influenced by the alterations in hemodynamics as a result of these abnormalities.

When hydrops is present, lung maturity has traditionally dictated treatment—immediate delivery in those fetuses with lung maturity and initiation of medical therapy when L/S ratios suggest lung immaturity. The antiarrhythmic agents most commonly used for transplacental therapy are digoxin, propranolol, procainamide, verapamil, and amiodarone. Digoxin is typically the drug of choice and may be given orally. Fetuses are followed clinically and with serial limited echocardiograms to aid management until delivery. Other antiarrhythmic drugs are administered intravenously as needed with the necessary medical support available for rapid obstetrical intervention as these agents may have serious side effects for the mother and fetus.

The evaluation of the fetal heart is a detailed process requiring a segmental approach in the visualization of all cardiac structures and function. Ref-

erences are provided for the guidelines of the American College of Cardiology, the American Heart Association, and the American Society of Echocardiography.[18,19] In summary, a team approach to the evaluation yields results that can aid in the delivery and management of patient and child.

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