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ASSESSING ANATOMY: SPECIFIC TECHNIQUES

Echocardiographic Techniques for Assessing Normal and Abnormal Fetal Cardiac Anatomy

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Diagnostic quality images of the fetal heart in utero can be obtained as early as 18 to 20 weeks of gestation. The cardiac structures can be imaged primarily by cross-sectional echocardiography and augmented by a combination of simultaneous M-mode echocardiography and range-gated pulsed Doppler ultrasonography. Cross-sectional images from planes through the fetal heart equivalent to planes that can be obtained after birth can be generated in utero. In a study of 168 pregnancies, 10 structural cardiac abnormalities have been defined. These abnormalities and others that have been reported indicate the potential for in utero cardiac diagnosis. The recognition of structural congenital heart disease in utero has been helpful in genetic counseling, planning the method of labor and delivery and making decisions regarding termination of pregnancy and planning postnatal care. Fetal echocardiography offers the potential to change the pattern of health care delivery to those with suspected congenital heart disease.

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Cross-sectional (two-dimensional) echocardiography has become a useful means for imaging the heart in utero (1–18). Cross-sectional and M-mode echocardiography and pulsed Doppler ultrasound can be used to define fetal cardiac structure, monitor cardiac development in utero and define blood flow patterns. The assessment of cardiac anatomy in utero is useful for examining cardiac structure, providing genetic counseling, treating cardiac arrhythmias and planning the means of delivery of the infant and its postnatal care. If serious cardiac abnormalities are found early enough in gestation, there is the potential for therapeutic abortion, for transplacental or intra-amniotic administration of drugs or, as recent studies (19) on the use of intrauterine surgery have shown, for some form of prenatal intervention to be performed.

Modalities of Ultrasound Used for Structural Cardiac Definition

Cross-sectional (two-dimensional) echocardiography is the most valuable mode of ultrasound for detection of structural cardiac abnormalities. Two presentation formats are currently used for cardiac structural diagnosis. Most commonly used is the sector or pie-shaped format produced by phased array or mechanical scanners. However, the rectangular format of the linear array transducers has also been used. Each of these formats offers advantages and disadvantages.

The sector format shows larger fields of view as the distance from the transducer increases. However, the scan lines diverge with increasing depth, there is less actual information between scan lines available for analysis, regardless of the introduction of electronic smoothing techniques. This format is useful for examining the fetus when there is limited ultrasonic access due to fetal position within the pelvis of lower abdomen. It is also preferable to generate images from the abdomen that are not obscured by rib or vertebral shadows. The rectangular format of the linear array system offers the same resolution throughout the field of view. The linear array transducer is slightly easier to manipulate than the sector transducer, but with experience, information can be obtained with either type of apparatus. Using either system, images of the fetal heart obtained through the fetal abdomen are preferable because rib and vertebral shadows may obscure cardiac structures.

Cardiologists have used the sector transducer almost exclusively because of its wide acceptance as a postnatal tool. The sector format includes M-mode and pulsed Doppler ultrasound and is, therefore, generally more useful for cardiac examination. State of the art ultrasonic diagnosis of structural cardiac abnormalities in the fetus must employ all three modalities, which are widely available in sector rather than linear scanners.

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Although M-mode echocardiography had been used to define cardiac structure in utero, its ability to define structure more precisely has been enhanced when used simultaneously with cross-sectional imaging. Chamber dimension and valve and wall motion can be as readily detected in utero as they can after birth. The addition of M-mode echocardiograpy to sector scanners has greatly improved the yield of high quality M-mode and cross-sectional echocardiograms. Not only has this marriage of the two modalities of ultrasound provided the ability to recognize the M-mode structures more rapidly, but conversely, the recognition by M-mode echocardiography of the characteristic patterns of atrioventricular and semilunar valve motion together with the patterns of contraction of the various cardiac structures has facilitated the more rapid recognition of cardiac structure with the cross-sectional echocardiographic technique (Fig. 1).

The advent of range-gated pused Doppler ultrasound incorporated into a system with M-mode and cross-sectional

Figure 1. Top, The short-axis cross section through the right ventricle (rv) and left ventricle (lv) of a fetus with a gestational age of 31 weeks. The M-mode line is passing through the center of the ventricles in the position suitable for recording an M-mode echocardiogram. The scale marker with centimeter and half centimeter marks is indicated on the **right**. **Bottom**, M-mode echocardiogram. The 1 cm marker is displayed and the paper speed markers are 0.2 second apart for the large markers and 0.04 second apart for the small markers. The paper speed was run at 100 mm/s. mv = mitral valve; s = septum; tv = tricuspid valve.

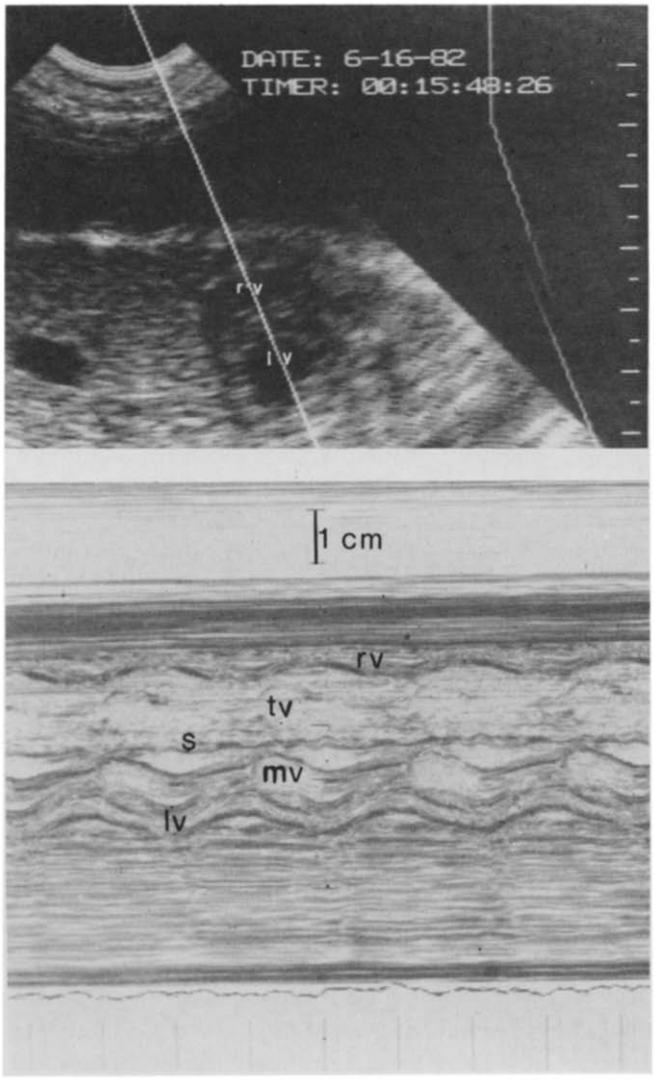
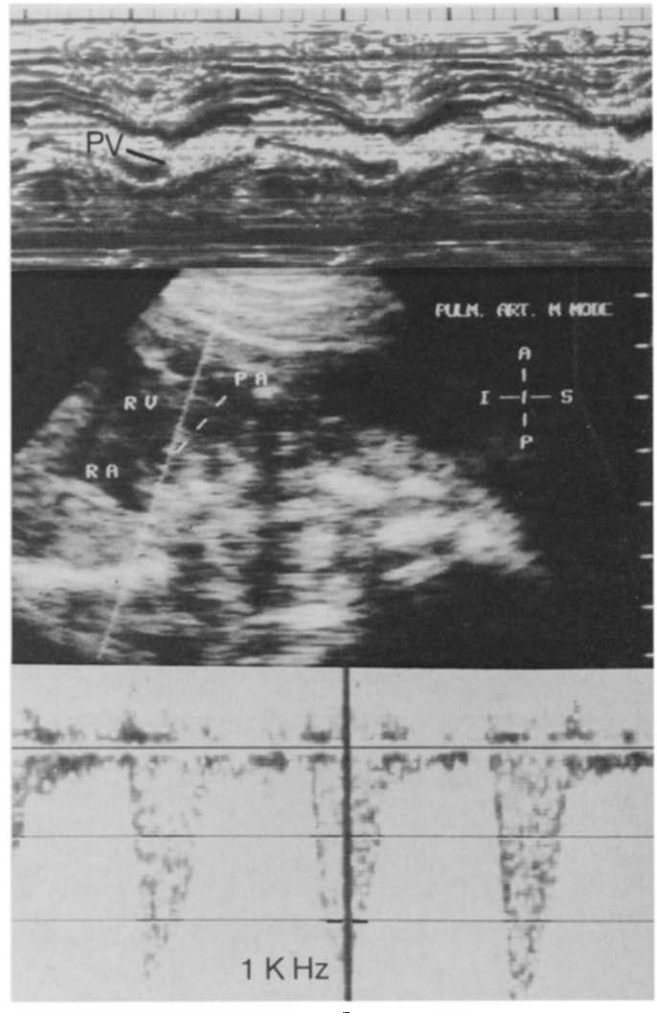


Figure 2. Demonstration of the three techniques used for validation of fetal cardiac structure. The **top panel** demonstrates the characteristic M-mode echocardiogram of the pulmonary valve (PV). The **middle frame** demonstrates the cardiac structure with the M-mode line passing through the pulmonary artery (PA). The pulmonary valve leaflets in this frame are in the open position. The orientation shows the fetus lying with its chest anterior (A), its back posterior (P), the feet inferior (I) and the head superior (S). The right atrium (RA) and right ventricle (RV) are also labeled. **Bottom panel**, With the pulsed Doppler mode, a characteristic arterial flow trace is seen. The baseline is represented as the **top line** in the Doppler trace and the scale markers represent 1 KHz of Doppler frequency. As the blood is flowing away from the transducer, the direction of flow is away from the baseline.



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echocardiography has further increased the rapidity with which cardiac structures may be identified (Fig. 2). The range-gated spectral Doppler recording defines the direction and characteristics of blood flow within each chamber and vessel, enabling the examiner to define directional flow within the heart and obtain a qualitative and quantitative assessment of the dynamics of blood flow.

Method of Echocardiographic Imaging In Utero

Localizing fetal position. The initial part of the examination is performed to localize the fetal position. The head and body position are defined to orient the examiner to the left-right, superior-inferior and anteroposterior positions (Fig. 3). The abdominal circumference and cranial biparietal dimensions are measured to establish whether the fetus is an appropiate age (20). If the fetus is lying with its back situated too close to the maternal abdominal wall, it may be necessary to rotate the mother onto one or the other side or elevate her head or feet to image the fetus from a slightly different approach. The vertebral column and ribs should not be directly in front of the heart because they absorb a considerable amount of the sound energy, thereby diminishing the acuity of the cardiac image. If this maneuver fails, the mother is asked to walk around for a few minutes in an attempt to change the fetal position.

Recording site. When doubt exists about a structure, the study should be repeated within 2 to 3 weeks to ensure adequate examination. It is best to obtain images of the heart through the fetal abdomen because they are of much higher quality than those obtained either through the precordium or from the back where rib and bone shadows may obscure the image. The echocardiographic "window" for examining the fetal heart may also be limited by the fetal position and the limbs. Because the transducer is some distance from the heart, even slight transducer movements of a few degrees are likely to cause the scan field to pass out of the area where the heart is located. The examiner may have difficulty maintaining the transducer position because of active fetal movement.

Unlike the postnatal situation, it is possible to perform examinations from the posterior aspect of the fetus. Also, because the lungs are filled with fluid, it is possible to obtain images of the heart through the rib cage. When recordings are obtained through the back, the M-mode image is displayed upside down relative to conventional display. These can be oriented to a conventional position by holding the recording upside down and viewing the image in a mirror. In addition, as one becomes accustomed to viewing the

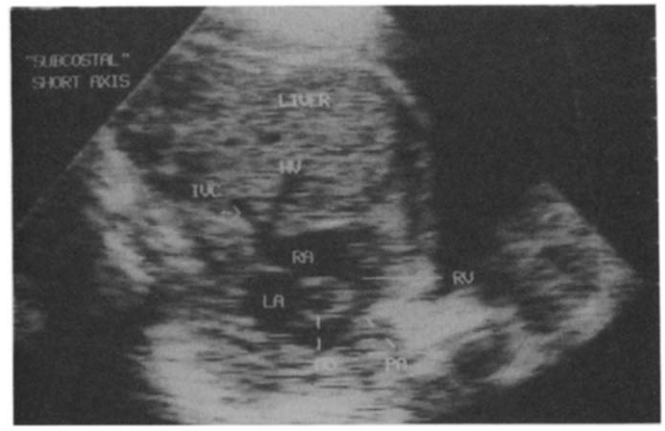

Figure 4. Subcostal short-axis view of a 30 week old fetus demonstrating the fetus lying with its abdomen toward the transducer. The transducer plane passes from the liver through the heart. The hepatic vein (HV) and inferior vena cava (IVC) can be identified and are seen to enter the right atrium (RA). The right ventricle (RV) can be traced around the aorta (AO) and into the pulmonary artery (PA). The aortic valve can also be identified. The right atrium is separated from the left atrium by the atrial septum. The scan passes through the open foramen ovale. In this and subsequent scans, the calibration on the **right** is at 1 cm intervals.

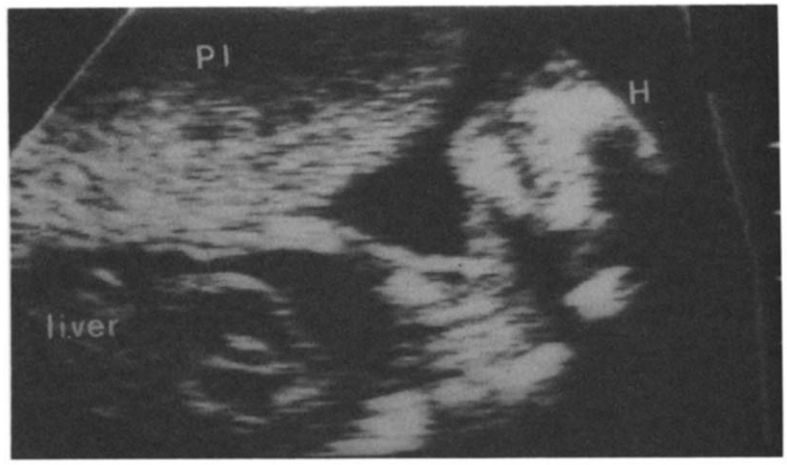

Figure 3. Longitudinal scan through an 18 week old fetus defining the overall position. The fetal head (H) with the eye sockets and oral cavity can be clearly defined. The neck can be identified and the cardiac structure seen within the thorax. The liver can be identified within the abdomen. The placenta (Pl) is seen lying anterior to the fetal thorax. A large pericardial effusion surrounds the heart. If one were to place oneself in the position of this fetus, then cranial-caudal, left-right and anterior-posterior positions can be defined for the purposes of orientation for the examination. This fetus had nonimmune hydrops without structural cardiac disease.

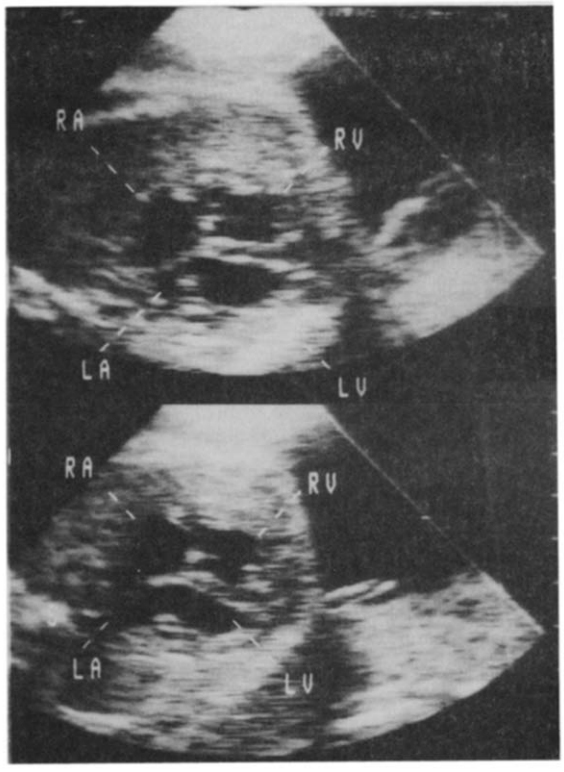

Figure 5. Four chamber view from the same fetus as in Figure 4, demonstrating normal intracardiac anatomy. The two frames show systolic frames with the atrioventricular valve leaflets closed and diastolic frames with the leaflets open. The right side of the fetus is toward the transducer. In the **top frame**, in systole, the right atrium (RA), right ventricle (RV), left atrium (LA) and left ventricle (LV) are separated by their respective septa and atrioventricular valves. The heavy trabeculations within the apex of the right ventricle represent the anterior papillary muscle and moderator band apparatus. Note that the right-sided structures occupy a larger area than the left-sided structures in the fetus. In the **bottom frame**, in diastole, the spine (S) is seen as an additional reference lying close to the left atrium. The foramen ovale is in an open position with the primum septum deviated into the left atrium and a faint echo from the eustachian valve demonstrable in the right atrium near the crux of the heart. The inferior vena cava drains into the right atrium adjacent to the atrial septum.

image in the unconventional orientations, it becomes as easy to read as the conventional cross-sectional or M-mode images.

Timing of examination. Satisfactory diagnostic ultrasound images of the fetal heart are possible from as early as 14 to 16 weeks' gestation (6), but in our experience reasonable accuracy is only possible after this time. The preferred time for examination is from 18 weeks of gestational age onward. We have concentrated on fetuses with a gestational age of 20 to 22 weeks in the hope of determining cardiac defects and assisting genetic counseling. Generally, the most satisfactory resolution is achieved at 20 weeks of gestation and older; we attempt to perform at least one examination during this gestational period.

Viewing approaches. Because of the fetal position and the limited transducer access, it may not be possible to obtain the equivalent view that can be obtained after birth. Nevertheless, adequate numbers of planes must be obtained to satisfy the criteria for a complete examination of all the cardiac and vascular structures. We attempt to obtain planes of examination equivalent to four chamber, short-axis and long-axis views in each study. Because of limited access and because the fetus may turn during examination, these views should be recorded as they are identified, rather than obtained in a set sequence similar to that which is conventionally used after birth.

Four chamber view. The inferior vena cava usually can be traced to the right atrium by cephelad manipulation of the transducer (Fig. 4). This position allows a reference point from which the transducer can be angled and moved slightly toward the heart in a cranial direction with the plane kept fairly horizontal until the four chamber view is displayed (Fig. 5). The four chamber view is situated in a more horizontal plane than in the postnatal period because of the large liver (7). The eustachian valve, which is prominent in the fetus, can often be identified within the right atrium where it may function to direct highly saturated blood toward the left atrium and the upper body. In addition, the primum component of the atrial septum can be identified in the left atrium. The phasic motion of the primum component of the septum demonstrates the interatrial dynamics in utero.

In the four chamber view, the two atrioventricular (AV) valves can be identified. The right ventricle is usually slightly larger than the left ventricle (3), and the moderator band can frequently be identified. The tricuspid valve is positioned slightly closer to the cardiac apex than is the mitral valve. The spine, lying close to the left atrium, and the stomach, which is filled with fluid and appears "cystic," are additional reference points. As in the postnatal period, AV canal defects can be identified from this plane. This is a useful view for performing M-mode echocardiography to define arrhythmias because the simultaneous M-mode image produced from one of the scan lines can generate information regarding AV valve motion and atrial and ventricular contraction. This view is also useful in defining ventricular and atrial size, examining AV valve morphology and defining septal defects.

Long-axis view. The long-axis view is similar to that obtained after birth (Fig. 6). The transducer is angled from the fetus's right shoulder to its left hip and manipulated slightly to obtain a recognizable long-axis image. With slight rotation toward the left, the pulmonary valve can be seen (Fig. 7). With slight manipulation, it is also possible to define the entire aortic arch (Fig. 8). Potentially, aortic coarctation, interruption and atresia may be defined from this plane. Clearly, these optimal views are not obtainable in all fetuses.

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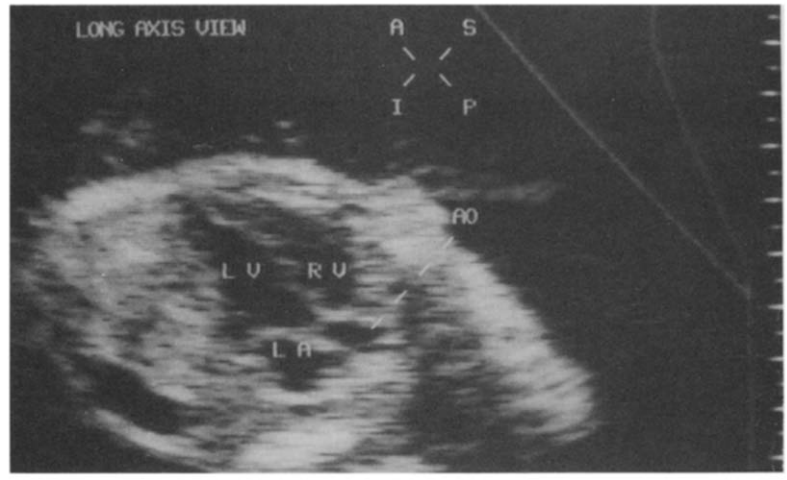

Figure 6. A long-axis view in a normal 22 week old fetus. The left ventricle (LV) is separated from the left atrium (LA) by the mitral valve. The left ventricular outflow tract can be traced into the aorta (AO) through the aortic valve. The right ventricle (RV) is situated anteriorly. A = anterior; I = inferior; P = posterior; S = superior.

Short-axis view. The short-axis views can be obtained with slight manipulation of the transducer into a plane almost parallel to the fetal spine. The most cephalad short-axis view shows the pulmonary artery and right ventricular outflow tract as they course around the aorta. The bifurcation of the pulmonary artery can be identified, although in the fetus the pulmonary branches are small. The ductus arteriosus can be identified and traced into the descending aorta (Fig. 9). Also, both the aortic and pulmonary valves can be identified from this plane. Theoretically, this tomographic plane affords the potential for differentiating transposition of the great arteries, pulmonary atresia, aortic atresia, double outlet right ventricle and truncus arteriosus from normal anatomy; but as noted, a specific diagnosis should not be made from a single plane. With caudad and more horizontal angulation from this plane, the ventricles and their respective AV valves can be identified (Fig. 10).

Results

Fetal ventricular septal defect. The indications for fetal study have been numerous (Table 1). To date, we have examined 167 fetuses in the second and third trimester of pregnancy (Table 2). We examined 10 fetuses with congenital heart disease. In three of these, a ventricular septal defect was identified; it was confirmed in two of the three at postmortem study after therapeutic abortion. In the third, a perimembranous ventricular septal defect was defined on ultrasound examination at 18 weeks' gestation. Serial examination in this fetus showed progressive diminution in the size of the defect until it could no longer be defined. At birth, this infant was found to be normal.

Fetal AV canal defect. An AV canal defect was recognized in three fetuses. In two of the three, it was associated with a cardiac arrhythmia. Both of these fetuses had

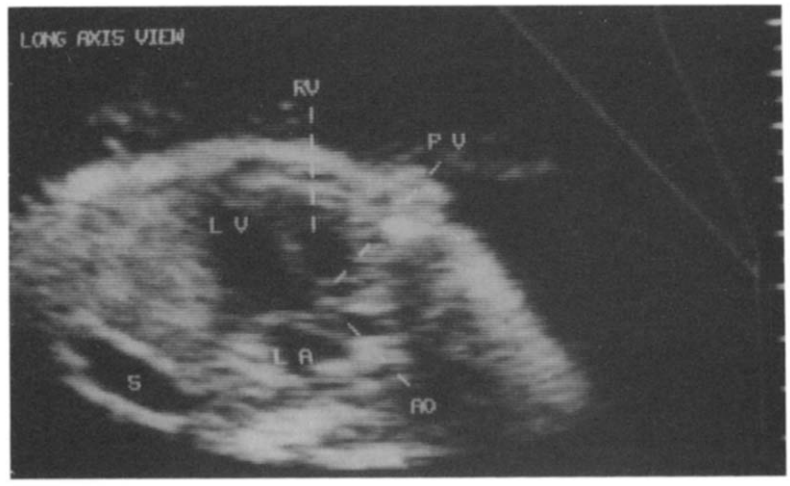

Figure 7. The same fetus as in Figure 6. With a slight leftward angulation, the pulmonary valve and a small portion of the pulmonary artery can be demonstrated. AO = aorta; LA = left atrium; LV = left ventricle; PV = pulmonary valve; RV = right ventricle; S = stomach.

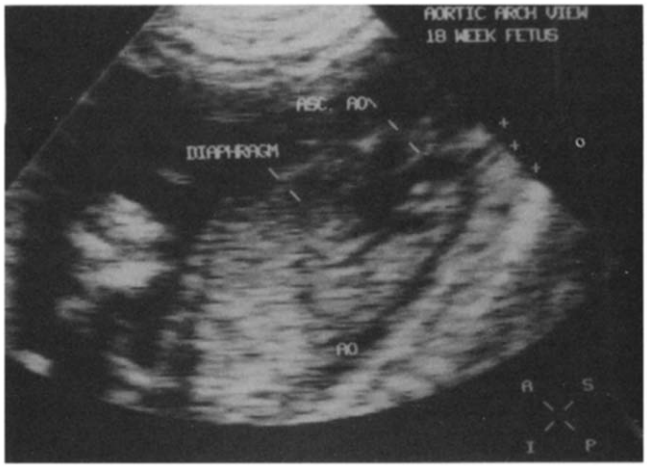

Figure 8. The aortic arch viewed from a long-axis plane in an 18 week old fetus. The entire aortic arch is demonstrated from the ascending aorta (ASC. AO) through the descending aorta (AO) to well below the level of the diaphragm. The + signs demonstrate the origins of the three great vessels to the head and neck in normal sequence. A = anterior; I = inferior; P = posterior; S = superior.

splenic anomalies at postmortem examination, as well as an AV canal. One fetus had complete heart block and associated nonimmune hydrops. The other fetus had a complex arrhythmia with Mobitz type I second degree AV block at times, and 2:1 AV block at others. There were frequent premature ventricular complexes. The first fetus of 38 weeks' gestation also had ventriculoarterial discordance and pulmonary stenosis. The latter abnormalities were not found by ultrasound. In the second fetus, the AV block was noted at 36 weeks' gestation and the splenic anomaly suspected because of the abnormal inferior vena cava pathway. The prenatal and postnatal echocardiograms in this fetus are shown (Fig. 11). In addition, Doppler ultrasound was used to define the presence of AV valve regurgitation. Because of the poor prognosis of this fetus, the obstetricians elected to deliver this infant by vaginal delivery rather than cesarean section. This infant could not be sustained without mechanical ventilation and pressure agents to maintain its blood pressure. Therapeutic support was discontinued. At postmortem examination, a primitive type of AV canal defect and polysplenia (left isomerism) were defined. There was a primitive common atrium that was markedly enlarged because of gross AV valve insufficiency. The great arteries were normally related.

Defects associated with polyhydramnios. Many mothers were referred for ultrasound examinations because of polyhydramnios. In one fetus at 23 weeks' gestation, nonimmune hydrops and a classic form of hypoplastic left heart syndrome with aortic atresia were found (Fig. 12). Because of these findings and after counseling, the parents elected to have a therapeutic abortion. At postmortem examination, the diagnosis of hypoplastic left heart complex was confirmed. Cardiomyopathy was detected in two other patients. The first fetus, 33 weeks' gestation by history, was small for dates from the estimation of the biparietal dimension, abdominal girth and femur length (20). Although polyhydramnios complicated the examination, a thick, poorly contractile left ventricle was found. One week after the cardiac examination, the mother went into premature labor and at birth, the infant had physical findings of left ventricular failure. At cardiac catheterization, the infant was found to have features consistent with congestive cardiomyopathy with mild mitral and tricuspid insufficiency. This child is still alive 2 years after birth and is maintained on a regimen

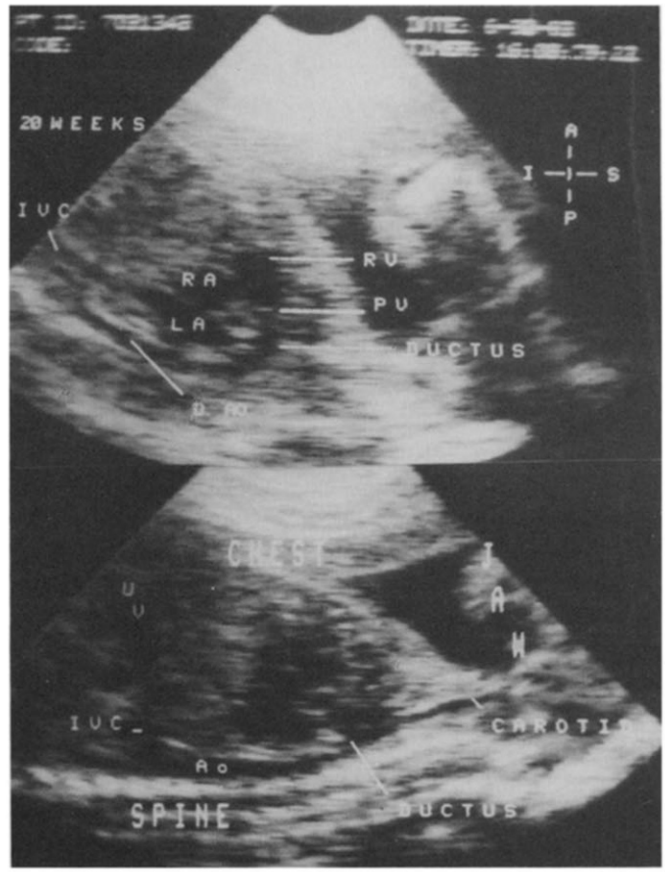

Figure 9. Demonstration of the descending aorta ductus continuity in the short-axis view in a 20 week old fetus. **Top frame,** A short-axis view at the base of the heart demonstrating the continuity between the right ventricle (RV), the ductus and the descending aorta (D. AO). The central aortic root is surrounded by the left atrium (LA), right atrium (RA) and right ventricle (RV). The pulmonary valve (PV) can be seen separating the right ventricle from the main pulmonary artery. A = anterior; I = inferior; IVC = inferior vena cava; P = posterior; S = superior. **Bottom frame,** View from the same fetus with slight rotation showing a slightly more vertical orientation than seen in the top frame. The carotid artery can be seen joining the aorta and the area of the ductus still appreciated. The position of the chest, spine and jaw defines fetal position and orientation of this cut. Ao = aorta; IVC = inferior vena cava; UV = umbilical vein.

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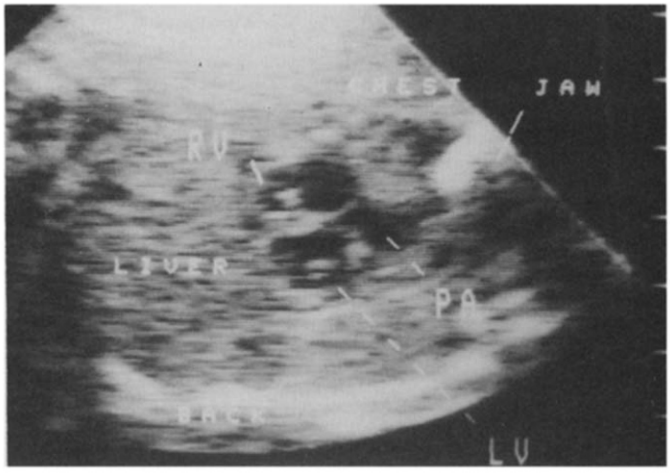


Figure 10. The short-axis view from the same fetus as in Figure 9 with slight caudal tilt of the transducer. The right (RV) and left (LV) ventricle can be seen with portions of their respective atrioventricular valve. The pulmonary valve can be seen separating the right ventricle from the pulmonary artery (PA). The position of the chest, liver, back and jaw defines the position of the scan plane.

of digitalis and furosemide. The second fetus with poor ventricular function died in utero and postmortem examination revealed endocardial fibroelastosis. Ten additional fetuses had nonimmune hydrops, and five of these had structural or rhythm disturbances, or both. In all of these, the polyhydramnios made examination difficult.

Finally, another pregnant mother was referred because she had taken 900 mg of lithium a day for depression during the first month of pregnancy. At 24 weeks' gestation, the fetus was found to have major tricuspid insufficiency by Doppler examination and displacement of the tricuspid valve consistent with Ebstein's anomaly (Fig. 13). The combined experience of several reports is illustrated in Table 3, which lists the diagnoses that have been correctly established in utero using echocardiography.

Discussion

Several factors make it difficult to define accurately the sensivity and specificity of fetal echocardiography in recognizing congenital heart defects. Our ability to accurately diagnose intrauterine defects has increased as a result of improved sectional echocardiographic equipment and the addition of high resolution M-mode and spectral Doppler capabilities.

Early experience. Before 1981 when we acquired our current state of the art ultrasound equipment, we conducted a study (12) to evaluate the accuracy of cross-sectional echocardiography in defining congenital heart defects in fetuses with chromosomal abnormalities who subsequently underwent therapeutic abortion. There were 19 fetuses in the study. In one, we were able to define an AV septal (canal) defect correctly, but failed to define the associated pulmonary atresia. In another, we erroneously defined an AV septal defect. There were two fetuses with bicuspid pulmonary valves and one bicuspid aortic valve which we were unable to define on the prenatal echocardiogram. In one fetus a secundum atrial septal defect present at postmortem examination had not been recognized on the in utero ultrasound examination. We were unable to detect double outlet right ventricle in one fetus. We also wrongly assumed tetralogy of Fallot in another instance. These errors of diagnosis were due to poor resolution of the images and

Table 1. Indications for Fetal Cardiac Ultrasound Examination

1. Family history of congenital cardiac abnormalities or hereditary disease affecting the heart.
2. Chromosomal abnormalities detected by amniocentesis.
3. Abnormalities of other organ systems detected by amnioscopy or ultrasound.
4. Fetal cardiac arrhythmia.
5. Nonimmune fetal hydrops.
6. Polyhydramnios or oligohydramnios.
7. Maternal ingestion of substances known to be associated with production of congenital heart disease.
8. Maternal disease known to affect the fetal cardiac status.
9. Intrauterine growth retardation.

Table 2. Prenatal Echocardiography in 167 Fetuses

Gestational Age (wk)	Structural Abnormalities	Outcome
18	VSD	Trisomy, VSD at postmortem
20	VSD	Trisomy, VSD at postmortem
30	VSD	Disappeared on serial sonography
33	AVSD	Multiple congenital defects, lesion confirmed by postnatal sonography
38	AVSD, complete heart block, nonimmune hydrops	Right isomerism (asplenia), corrected transposition, AVSD
36	AVSD, splenic anomaly, complex arrhythmia, nonimmune hydrops	Left isomerism (polysplenia), interrupted inferior vena cava, AVSD
22	Aortic atresia, hypoplastic left ventricle, nonimmune hydrops	Termination of pregnancy, same diagnosis
32	Cardiomyopathy, polyhydramnios	Cardiomyopathy
36	Cardiomyopathy, polyhydramnios	Cardiomyopathy
24	Ebstein's anomaly, tricuspid insufficiency, heavy lithium ingestion	

AVSD = atrioventricular septal defect; VSD = ventricular septal defect.

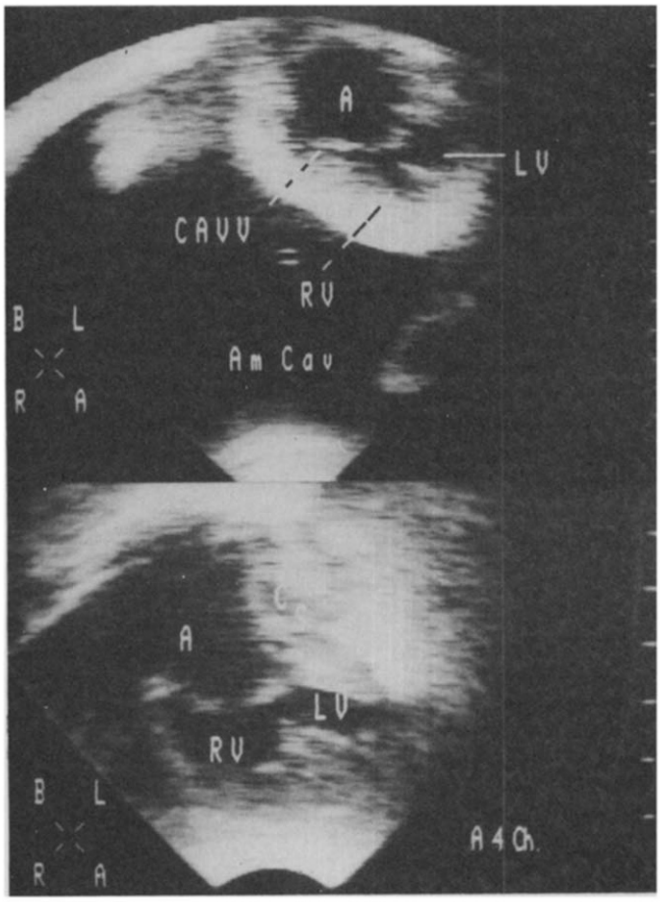


Figure 11. Pre- and postnatal echocardiograms in a 36 week old fetus with an atrioventricular septal defect. A large atrium is identified with no demonstrable atrial septum. A common atrioventricular valve (CAVV) is seen straddling the ventricular septum, which separates the left ventricle (LV) from the right ventricle (RV). The ventricular component of the defect is seen below the valve. Polyhydramnios is present and the amniotic cavity (Am Cav) is extremely large. The position of the base (B), and apex (A), and left (L) and right (R) are shown at the **lower left**. **Bottom frame**, Echocardiogram in the same plane obtained shortly after delivery of the infant. No atrial septal defect could be defined, but a large left superior vena cava coronary sinus connection was present. The view used to generate this image was an apical four chamber plane (A 4 Ch). The 1 cm scales in the two images are different.

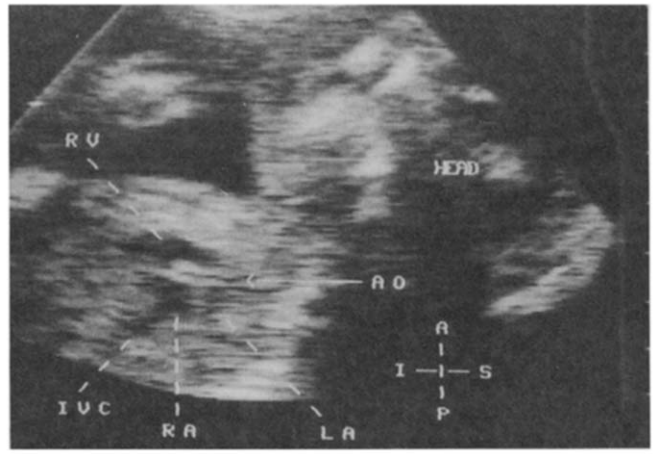


Figure 12. Long-axis scan demonstrating the classic findings of aortic atresia in a 23 week old fetus. A minute ascending aorta (AO) can be seen. The right ventricle (RV), right atrium (RA) and left atrium (LA) can also be defined. The inferior vena cava (IVC) can be seen draining into the right atrium. No left ventricle could be identified when scanning this fetus. A = anterior; I = inferior; P = posterior; S = superior.

overzealous interpretation. Similarly, structural abnormalities were missed due to inadequate resolution or fetal position precluding adequate examination.

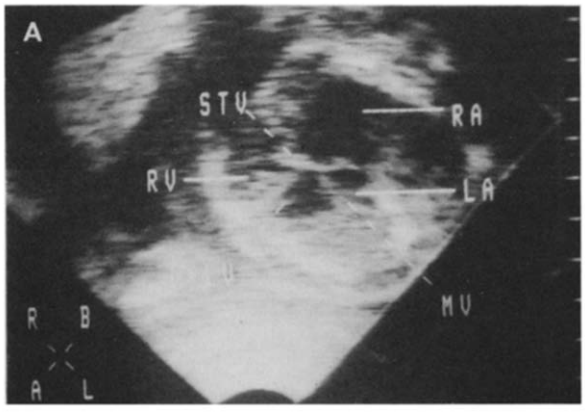
These errors were made early in our experience with suboptimal equipment and without the use of all modes of ultrasound. The findings emphasized that meticulous and careful examination with high resolution equipment was necessary for in utero cardiac examination. Several publications (2,6,7,10,14) reported errors or incomplete diagnosis of in utero cardiac abnormalities.

Later studies. Since the acquisition of the latest equipment with high frequency crystals and M-mode and spectral Doppler capabilities, we have not made major errors. We have recognized major abnormalities, but with complex defects, complete delineation of the associated lesions may not be possible either before or after birth. This incomplete delineation becomes important when one considers the potential for actions, such as termination of pregnancy, fetal surgery or the use of medication administered transplacentally or directly into the amniotic cavity.

Five of the 10 infants in our study (Table 2) had associated polyhydramnios. The fetus is frequently at a greater distance from the transducer than it would be without hydramnios and this makes the study technically more difficult. Under these circumstances, the cardiac structures are frequently in that area of the sector fan where resolution is suboptimal. It is remarkable that even with the potential for error mentioned, the technique has been precise, as attested to by the extensive list of confirmed abnormalities that have been recognized.

Ultrasound offers the ability to examine cardiac structures in utero, which is unavailable with other techniques. It is noninvasive and, at worst, offers only a potential risk to the fetus. Although there are numerous studies that defined potential hazards of ultrasound in experimental situations, no clinical study to date has reported any deleterious effect on any fetus which can be directly attributable to ultrasound (21,22).

Future directions. It is still too early to evaluate whether there are any advantages or disadvantages to the technique itself. There appears to be no other imaging mode that can be compared with ultrasonography for defining abnormalities of fetal cardiac structure and function noninvasively. With the continuing improvement in the overall resolving



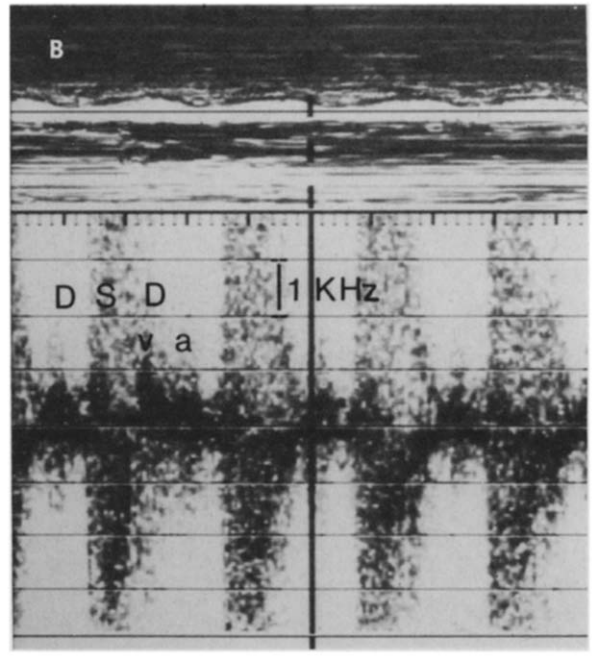


Figure 13. A, Four chamber image generated from a fetus with Ebstein's anomaly of the tricuspid valve. In this four chamber plane, the right atrium (RA) is enlarged and the right ventricle (RV) is smaller than the left ventricle (LV). The planes of the mitral valve (MV) and septal leaflet of the tricuspid valve (STV) are shown. The displacement between the septal leaflet of the mitral valve and tricuspid valve is approximately 0.5 cm. A = anterior; B = base; L = left; LA = left atrium; R = right. **B**, Doppler recording obtained within the right atrium. The sample volume is seen on the M-mode portion of the recording within the right atrium adjacent to the echo of the atrioventricular valve. In the Doppler portion of the recording, the **central line** represents the baseline, and the division shows 1 KHz of frequency shift. The points v and a in diastole (D) represent phasic forward flow into the ventricle. In systole (S), flow is away from the transducer toward the atrium. There is severe aliasing of the Doppler signal and findings on this recording are consistent with tricuspid insufficiency.

abilities of ultrasound to define cardiac structure and function, the technique appears to have enormous potential.

Whereas nuclear magnetic resonance may offer some potential for fetal diagnosis, it has not been used in this area. Damage to fetal tissue from this technique has not been evaluated. It seems unlikely, with the potential cost and other more pressing demands on the use of this new technology, that it will be used as a screening technique for fetal ultrasound.

During pregnancy, a large proportion of women in the United States undergo sonographic examination performed under the supervision of obstetricians and radiologists, rather than pediatric cardiologists who are familiar with the ultrasound patterns of congenital heart disease. Consequently, many mothers whose infants had serious congenital heart

Table 3. Lesions Successfully Diagnosed In Utero by Cross-sectional Echocardiography

	Reference No.
Transposition of the great arteries	16
Pulmonary atresia and right ventricular hypoplasia	2
Single ventricle	2,14
Premature closure of foramen ovale	5
Tetralogy of Fallot	10,11
Tricuspid atresia	15
Coarctation of the aorta	6
Septal rhabdomyoma	10,14
Hypoplastic left ventricle	17,18,*
Hypertrophic cardiomyopathy	13
Atrioventricular septal (canal) defect	6,7,10,12,16,18
Myocardial infarction	10,1
Cardiomyopathy	3,10,*
Premature closure of the ductus arteriosus	14
Conjoined twin: definition of cardiac status	14
Ebstein's anomaly of the tricuspid valve	*
Ventricular septal defect	10,12,16,*
Aortic stenosis and endocardial fibroelastosis	7,16,17
Double outlet right ventricle	7
Ectopia cordis	14

*Present report.

disease have had prior fetal sonographic studies in which these fetal cardiac abnormalities were not defined. In the future, it may be possible if these cases can be identified that some form of prenatal therapy, be this medical or surgical, can be undertaken in a large proportion of fetuses affected with congenital heart disease. If major cardiac abnormalities are discovered before the 24th week of gestation, it may be possible to offer the parents the opportunity for terminating the pregnancy for the more complex forms of congenital heart disease. Clearly, a considerable amount of education and dissemination of the experiences of those working in this new field are necessary to provide those primary diagnosticians in the field of ultrasound, namely radiologists and obstetricians, with the ability to recognize normal from abnormal cardiac anatomy. The role of ultrasound cardiovascular imaging in the prenatal patient may radically alter the approach to health care delivery to those with suspected congenital heart disease.

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