Doppler Echocardiography in the Diagnosis and Management of Persistent Fetal Arrhythmias

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Thirteen fetuses with persistent arrhythmias underwent combined noninvasive echocardiographic evaluation utilizing M-mode, two-dimensional and pulsed Doppler echocardiography. This group (Group A) was compared with 14 fetuses in which only two-dimensional and M-mode echocardiographic evaluations were performed (Group B). In both groups correct prenatal interpretation of the arrhythmia was confirmed by postnatal electrocardiograms in all surviving fetuses. Although Doppler echocardiography was not more sensitive than M-mode echocardiography in the interpretations of the arrhythmia, Doppler tracings of sufficient quality to analyze rate and rhythm were easier to obtain in all cases and provided additional information about valvular incompetence and the functional state of the fetal heart. Cardiac malformations and hydrops fetalis were commonly associated with persistent arrhythmias. Congenital heart disease occurred frequently (6 of 11) with complete atrioventricular (AV) block. Pulsed Doppler echocardiography defined the AV contraction sequence, atrial and ventricular rates and AV valve insufficiency, allowing rapid interpretation of fetal arrhythmias.

Methods

Definition of persistent fetal arrhythmias. A persistent fetal arrhythmia was defined as an abnormality in fetal cardiac rhythm in which the ventricular rate was greater than 180/min, less than 100/min or irregular. The arrhythmia was detected on one or more examinations before the onset of labor. To be included in the study the fetal arrhythmia must have persisted after delivery or disappeared as the result of postnatal medical treatment. This definition excluded fetuses with commonly observed transient intrauterine heart rate abnormalities, which may be present in up to 10% of normal fetuses, including normal beat to beat variability and arrhythmias occurring only during labor.

Study group. Between January 1978 and June 1985, 27 fetuses with persistent arrhythmias underwent combined evaluation by members of the Obstetrical Perinatology and Pediatric Cardiology divisions of our hospitals. The fetal gestational age at diagnosis ranged from 18 to 39 weeks (mean 32). These patients represented 20% of fetal cardiac evaluations. Obstetric ultrasound was obtained for assessment of fetal and placental growth and extracardiac malformations.
formations. All fetuses had combined two-dimensional and M-mode echocardiograms using ATL 600 MK or Acuson-128 ultrasound/Doppler equipment and previously described methods of segmental examination (6–10).

Doppler echocardiographic evaluation. Since 1983, 13 of the 27 fetuses with persistent arrhythmias have had pulsed Doppler echocardiographic evaluation using a 3 or 5 MHz transducer and limiting energy output and exposure time (Group A). Doppler sample volume size ranged from 2 to 5 mm². Doppler tracings were recorded at 100 mm/s paper speed with standard 1 second calibration lines. The heart rates were measured from the baseline at the onset of flow or at peak flow velocity when minimal upstroke variability was present. Two views were routinely obtained for rhythm assessment (Fig. 1). The ventricular rate and AV contraction sequence were determined by sampling in the area of fibrous continuity between the aortic and mitral valves in an apical four chamber view equivalent. From this position (position A), ventricular inflow and outflow could be recorded simultaneously, and the AV contraction sequence could be determined, allowing the identification of atrial flutter and complete AV dissociation, as well as atrial and ventricular extrasystoles. A normal AV Doppler flow velocity consisted of rapid diastolic filling and atrial systole followed by ventricular systole (Fig. 2). We compared each surviving patient’s fetal records with that patient’s neonatal and infant records of simultaneous Doppler echocardiograms and electrocardiograms taken during sinus rhythm. During systole, ventricular flow is in the direction opposite to the mitral valve inflow velocity. Atrial systole is more prominent in the fetus than in the newborn.

The atrial rate was confirmed by Doppler sampling at the fossa ovalis to record the flow velocity from the right to the left atrium (position B) (Fig. 1). In Figure 3, normal sinus rhythm and supraventricular tachycardia in a 28 week fetus are demonstrated. Comparable views in the neonate do not demonstrate right to left atrial shunting during systole in sinus rhythm.

Limited Doppler echocardiograms were repeated in six patients to assess the continued presence of tricuspid insufficiency. Doppler study was performed in four patients in the neonatal period during the persistent arrhythmia to confirm the flow patterns detected prenatally, and electrocardiograms were obtained postnatally during the arrhythmia in all 19 surviving infants.

Before 1983, 14 of the 27 fetuses were evaluated using standard methods of noninvasive rhythm diagnosis combining imaging and two-dimensional-directed M-mode echocardiography (12). No blinded M-mode echocardiographic evaluations were attempted. Fetuses were evaluated at 2 week intervals unless hydrops fetalis or transplacental pharmacologic therapy necessitated more frequent follow-up.

Results

Arrhythmias in the 27 fetuses were AV block in 11, tachycardia in 10 and atrial premature contractions in 6.

Rhythm diagnosis. The prenatal rhythm diagnosis was confirmed electrocardiographically in 18 surviving infants who continued to have tachycardia postnatally; 1 infant has not had recurrence of supraventricular tachycardia while receiving postnatal digoxin therapy. Four had postnatal Doppler echocardiographic confirmation of the in utero flow patterns during arrhythmias, further supporting the cardiac rhythm diagnosis by Doppler techniques.

Doppler echocardiography (Group A). Doppler echocardiography allowed correct antenatal arrhythmia interpretation in all 13 cases. Doppler study was not more sensitive than M-mode recording in the same fetus in the interpretation of the arrhythmia, but interpretation was more rapid. Doppler examination also allowed detection of AV valve regurgitation and diastolic regurgitation in complete heart block (12).

Atrial premature contractions characteristically showed an early atrial systolic flow pattern followed by prolonged mitral inflow. The Doppler velocity findings of nonconducted atrial premature contractions are shown in Figure 4. No ventricular systolic flow pattern follows the early atrial premature contraction. Very early atrial premature contractions such as these may not produce a visible atrial flow velocity.

Figure 1. Illustration of Doppler sample volume positions. A. Area of mitral-aortic (Ao) fibrous continuity for recording ventricular rate and atrial-ventricular contraction sequence. B. Area of the foramen ovale for determining atrial rate. LA = left atrium; LV = left ventricle; RA = right atrium.
Figure 2. A, Normal atrioventricular (AV) contraction sequence recorded from the area of mitral-aortic continuity. A prominent atrial systolic velocity (A) as seen here is a normal finding in the fetus. The normal AV activation sequence is seen when the atrial deflection (A) immediately precedes left ventricular (LV) ejection (V). B, Doppler sampling in position A in the area of mitral-aortic continuity in an infant after birth with simultaneous echocardiography showing the timing of the P and R waves with respect to the Doppler correlates of atrial systole (A) and ventricular systole (V). Ao = aorta.

Figure 3. Atrial rates recorded from the foramen ovale position (position B in Fig. 1) during normal rhythm (left) and during supraventricular tachycardia (SVT) (right) in a 28 week fetus. BPM = beats/min; other abbreviations as in Figure 1.
During atrial flutter, variable degrees of AV block were present. Atrial flutter with 1:1 AV conduction could not be differentiated by Doppler or M-mode echocardiography from supraventricular tachycardia. No diagnosis could be confirmed in two fetuses dying in utero from hydrops fetalis and tachycardia with 1:1 AV conduction.

The Doppler evaluation of six fetuses with AV block demonstrated AV valve regurgitation in four and absent AV conduction in five (Fig. 5). Second degree AV block was present in one patient (Fig. 6).

M-mode echocardiography (Group B). The limitations of M-mode echocardiographic technique included 1) inability to record simultaneous atrial and ventricular contractions in 2 of the 14 patients, 2) poor quality tracings as the result of maternal obesity, polyhydramnios or fetal movement in 2 patients, and 3) dilated cardiac chambers resulting in limited atrial wall motion in 1 patient with complete heart block and a massively dilated common atrium.

Figure 5. Pulsed Doppler sampling in a 24 week fetus with left isomerism, atrioventricular (AV) canal defect and complete AV block. Upper panel. The pulsed Doppler sampling volume (top white arrow) is placed in the common atrium (CA) superior to the common AV valve orifice (CAVO) in a four chamber view equivalent where the apex of the heart and the right ventricle (RV) are seen. Lower panel. The Doppler velocity pattern is typical of complete heart block with AV valve insufficiency (AVVI). Atrial contractions produce velocity deflections (A) at a rate of 120 beats/min (BPM). Ventricular contractions (V) are marked by a high velocity jet of atrioventricular valve insufficiency at a rate of 35 beats/min with no relation between atrial and ventricular velocity deflections.
Prognosis of persistent fetal arrhythmias. Atrial premature contractions were benign and not associated with morbidity or mortality. The mortality in fetuses with complete AV block and tachycardia was 9 of 21. Two deaths were attributable to structural cardiac defects. Six of seven fetal patients dying of an arrhythmia had associated hydrops fetalis. Two fetuses with hydrops fetalis treated in utero for supraventricular tachycardia survived. Persistent arrhythmias presenting in the second trimester had a poor prognosis. Hydrops fetalis was present at the initial evaluation in four of five fetuses of less than 28 weeks’ gestational age, and all four died in utero.

Discussion

Appropriate management of the fetus with a persistent arrhythmia requires thorough prenatal echocardiographic evaluation. It is necessary to determine the type of arrhythmia, the presence of associated structural cardiac malformations, and the degree of hemodynamic compromise. Doppler echocardiography allowed rapid and correct assessment of atrial and ventricular rates and AV contraction sequences necessary to identify the type of fetal arrhythmia. Patients with ventricular tachycardia were not encountered in this study and data on the Doppler findings of this group are not yet available using a logical approach to rhythm (12).

Doppler versus M-mode echocardiography. Unlike M-mode and two-dimensional echocardiography, which detect only mechanical cardiac events, Doppler echocardiography is sensitive in detecting even low blood flow velocities. Until electrocardiographic diagnosis of arrhythmias is possible in the fetus, Doppler echocardiography appears to be a highly sensitive tool to assess myocardial flow patterns that can be used to infer the rhythm. Although M-mode echocardiography allows correct rhythm diagnosis in most cases, Doppler echocardiography may be necessary when M-mode tracings are technically inferior or inconclusive or when severe myocardial dysfunction compromises wall motion. Doppler rhythm interpretation is rapid and high quality two-dimensional images are not requisite for obtaining quality Doppler tracings.

Prognosis. The prognosis of the fetus with a persistent arrhythmia depends on the gestational age of the fetus, the type and duration of the arrhythmia, the degree of hemodynamic compromise, the presence of structural cardiac defects, the ability to treat the arrhythmia in utero and the fetal and neonatal response to therapy. Hydrops fetalis appears to be a late, nonspecific manifestation of severe fetal
cardiac decompensation. Its presence may be due to the arrhythmia, the structural cardiac defect, the AV valve insufficiency or a combination of factors. Doppler detection of AV valve insufficiency suggested significant fetal cardiac decompensation associated with cardiac dilation and structural cardiac defects (13).

Experienced perinatologists and cardiologists should care for these patients with persistent fetal arrhythmia. Thorough structural and functional prenatal echocardiographic and Doppler evaluation before and during treatment may decrease the mortality associated with these arrhythmias. Although Doppler echocardiography can be used to estimate transvalvular indexes, cardiac blood flows and right ventricular pressures in children after birth, experience with quantitation of Doppler recordings in the fetus is limited and requires further investigation.

References