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Authors
Moon-Grady, Anita
Shahanavaz, Shabana
Brook, Michael
et al.

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Can a Complete Fetal Echocardiogram Be Performed at 12 to 16 Weeks' Gestation?

Anita Moon-Grady, MD, Shabana Shahanavaz, MD, Michael Brook, MD, Hanoi Rodriguez, and Lisa K. Hornberger, MD, *San Francisco, California; Edmonton, Alberta, Canada*

Background: The aim of this study was to determine the feasibility of performing complete early fetal echocardiography (FE) at <17 weeks of gestation with comparison with standard FE in the midtrimester (17–23 weeks).

Methods: Fetal echocardiograms obtained in pregnancies studied at <17 weeks at the University of California, San Francisco, over a 5-year period were retrospectively reviewed. FE was considered complete if anatomic details could be assessed (systemic and pulmonary venous connections and atrial, ventricular, and septal [four-chamber sweeps], outflow and great artery, branch pulmonary artery, and arch anatomy) and if color and pulsed Doppler evaluations of the inferior vena cava, pulmonary veins, ventricular inflows and outflows, umbilical artery and vein, and ductus venosus were demonstrated.

Results: One hundred thirty-nine pregnancies were assessed by early FE at <17 weeks transabdominally during the study period (median gestational age, 14.0 weeks; range, 12-0/7–16-6/7 weeks). Additional transvaginal imaging was performed in 14 of 139 (10%) of early fetal echocardiographic studies. One hundred thirteen pregnancies were assessed using both early and later, standard (>17 weeks) FE. Of these, complete fetal echocardiograms were obtained in 27 early (24%; 95% confidence interval [CI], 17%–33%) and 76 later (67%; 95% CI, 58%–75%) exams. In most early exams, color and pulsed Doppler interrogation of the pulmonary veins was unsuccessful. If pulmonary vein Doppler assessment was excluded, complete studies were performed in 80 early exams (71%; 95% CI, 62%–78%) and 97 standard midtrimester exams (86%; 95% CI, 78%–91%). On early FE, heart disease was suspected in 20 pregnancies, and although no major congenital heart disease was missed, in four pregnancies, ventricular septal defects were found only on later FE or after birth.

Conclusions: Early FE yields nearly complete information (exclusive of pulmonary venous interrogation) in the majority of patients. (J Am Soc Echocardiogr 2012;25:1342-52.)

Keywords: Fetal echocardiography, First trimester, Transvaginal ultrasound, Congenital heart disease, Prenatal diagnosis

Second-trimester fetal echocardiography (FE) performed only after 17 weeks of gestation is a well-established technique for the detection and definition of complex cardiac malformation before birth.[1-3] Most forms of structural congenital heart disease (CHD), however, are present by the end of the first trimester and may even progress well before the standard midtrimester exam.[4,5] The detection of CHD beyond 17 weeks provides little time for further testing and decision making regarding termination versus continuation of pregnancy in most countries where standard termination is not offered at later gestational ages, and termination of pregnancy in the middle of the second trimester carries a higher risk than if performed earlier in gestation.[6,7] Finally, pregnancies at risk for fetal CHD are increasingly identified earlier in gestation using first-trimester screening, particularly with the implementation of ultrasound assessment of nuchal translucency.[8-10]

Despite the potential benefits of early FE, it is not routinely practiced in most fetal and pediatric cardiology programs internationally. This may at least in part be due to a lack of training in early FE. It is also likely due to the paucity of data regarding the details of the examination possible in earlier gestations. Since the early 1990s, many groups have reported their experience with imaging of the fetal heart at 10 to 16 weeks, but most have focused on imaging of basic fetal cardiac anatomy, including the four chambers and ventricular outflow tracts.[11-13] With technological advances in imaging and further experience, several investigators have documented successful prenatal detection of structural and functional abnormalities and arrhythmias at this early gestational age.[5,14-21] None of these studies, however, have specifically evaluated the anatomic and functional details possible at <17 weeks with what is currently the standard approach in the midtrimester.[22]

Abbreviations
CHD = Congenital heart disease
FE = Fetal echocardiography
2D = Two-dimensional

At our center, FE as early as 12 weeks of gestation has been offered for high-risk pregnancies since 2004, with confirmatory FE at or after 18 weeks gestation in most cases. We hypothesized that early FE (≤16-6/7 weeks) provides detailed structural and functional information at a similar frequency as mid-second-trimester (≥17 weeks) FE.

METHODS

A search of the database of the Fetal Cardiovascular Program at the University of California, San Francisco, was conducted to retrospectively identify all patients evaluated over a consecutive 5-year period (2004–2008) who underwent FE at <16-6/7 weeks; these patients were included in the descriptive analysis. Additionally, all patients undergoing repeat FE at ≥17 weeks were included in subsequent statistical analysis. This study was approved by the institutional review board at our institution (H41370-32744-01).

Echocardiography

All fetal echocardiographic studies were performed by American Registry for Diagnostic Medical Sonography–certified cardiac sonographers and/or board-certified pediatric cardiologists with expertise in FE.

All studies were performed using a Siemens Sequoia ultrasound system (Siemens Medical Solutions USA, Inc., Mountain View, CA). Studies performed before 17 weeks were done using an 8C4 or 10V4 phased-array transducer or an 8C4 curved-array transducer for transabdominal imaging and an Acuson EV-8C4 transvaginal transducer (Siemens Medical Solutions USA, Inc.) for transvaginal imaging. The highest frequency transducer was typically used for transabdominal imaging at the onset of the study, but if sufficient resolution could not be achieved because of the distance of the fetus from the maternal abdominal wall, a lower transducer frequency was used. If image quality was still insufficient, transvaginal imaging was attempted. Studies done after 17 weeks were performed using a 6C2 or an 8C4 curved-array transducer, per our protocol at the time for obstetric scanning. Transabdominal imaging at all gestational ages was performed using our laboratory's protocol on the basis of guidelines established by the American Society of Echocardiography.[22] This protocol included anatomic overview of the uterus, fetal number and lie, biometric examination, cardiac imaging and sweeps, Doppler examination incorporating color and pulsed-wave Doppler, and examination of heart rate and rhythm. Two-dimensional (2D) axial and sagittal 2-sec to 4-sec sweeps were used for demonstration of visceroatrial situs, systemic (superior and inferior vena cava and hepatic veins) and pulmonary venous connections (at least one left and one right pulmonary vein), atrial and ventricular arrangement and size, atrioventricular valves, outflow tracts, semilunar valves, and great artery size, arrangement, and patency. Color Doppler was used to demonstrate pulmonary venous return to the left atrium and atrioventricular and semilunar patency and to assess for regurgitation. Color Doppler interrogation of the ductal and aortic arches was performed in the sagittal plane. Pulsed-wave Doppler interrogation of the umbilical artery and vein, ductus

venosus, hepatic and inferior vena cava, tricuspid and mitral valves, outflows, right upper or left-sided pulmonary vein, and ductal and aortic arches was also performed. Figures 1 through 4 and Videos 1–7 (available at www.onlinejase.com) illustrate imaging and scoring examples.

Transvaginal scans were generally done in the same exam room; the patient was first asked to empty her bladder and then positioned with a bolster under her hips to tilt the pelvis, allowing more anterior imaging. The probe was then inserted in standard fashion, and multiple sagittal plane (in reference to the mother) images were taken. Sagittal and axial images through the fetus were attempted in each by rotating up to 180° and tilting the transducer to the mother's left and right and anteriorly and posteriorly, to allow evaluation of abdominal situs, four-chamber view, outflows, three-vessel view, and transverse views of the arches with 2D and color Doppler. Significant activity of the fetus at this early gestation also contributed to greater success of imaging of specific cardiac structures.

A retrospective review of the stored Digital Imaging and Communications in Medicine images was performed by two fetal cardiologists (L.K.H., A.M.-G.) for the presence or absence of the specific anatomic features listed in Table 1. In addition, completeness of the individual studies was assessed as follows: 2D assessment complete if systemic veins, four-chamber, right and left outflows, and arches were shown; Doppler complete if color and/or pulsed-wave of inflows and outflows, plus color of arches, pulsed-wave of cord and systemic veins, and pulsed-wave or color of pulmonary veins (inferior vena cava Doppler was optional as long as the ductus venosus was assessed). Studies were considered complete if both 2D and Doppler criteria for completeness were met.

Statistical Analysis

The presence of each of the scored parameters is expressed in terms of frequencies or percentages.

RESULTS

During the study period, 139 pregnancies met the inclusion criteria; 113 patients underwent both early and late FE. Sixteen fetuses underwent early FE only, without later echocardiography (most because the results of the first scan were normal and follow-up was not obtained by the referring clinicians) and are excluded from analysis. Eight had termination of pregnancy before a second scan (all abnormal results), and there were two with spontaneous intrauterine fetal demise before a second scan (one with pentalogy of Cantrell, one with cardiomyopathy).

All echocardiographic studies were performed for clinical indications, including pregestational diabetes (35%), family history of significant CHD (28%), increased nuchal translucency (16%), fetal arrhythmia (8%), teratogen exposure (4%), and others (9%), including gestational diabetes (diet controlled, White classification A1), assisted reproduction, multiple gestation, or suspected cardiac abnormality on screening ultrasound. Among the 113 study patients with two exams, FE performed from 12 to 16-6/7 weeks (median, 14 weeks) constituted the "early" studies, and FE performed from 17 to 23 weeks (median, 19 weeks) constituted "standard" studies (Figure 5).

In 125 of 139 early studies (90%), the entire study was performed using exclusively a transabdominal approach. In 14 pregnancies (10%), transvaginal ultrasound had also been performed by the clinician after initial transabdominal images had been obtained,
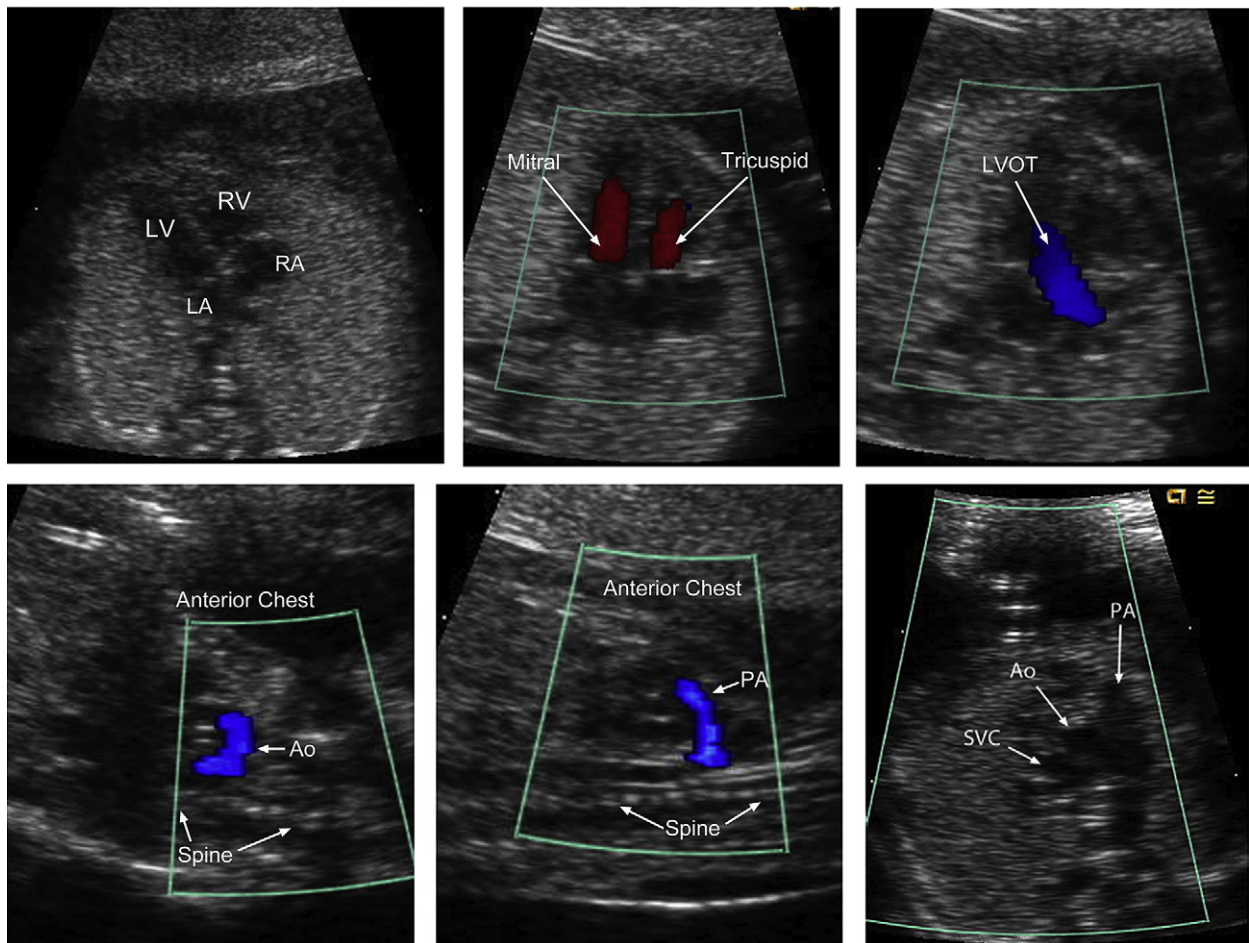
Figure 1 Normal survey images at 13 to 14 weeks obtained using a 10V4 transducer (transabdominal imaging). Clockwise from upper left, four-chamber, color Doppler of mitral and tricuspid inflows, color Doppler of left ventricular outflow, three-vessel and tracheal view (the right pulmonary artery and ductal arch are also visible), sagittal ductal arch with color Doppler, and sagittal aortic arch with color Doppler. Videos 1 and 2 (available at www.onlinejase.com) illustrate cine clips with 2D and color axial sweeps. *Ao*, Aorta; *LA*, left atrium; *LV*, left ventricle; *LVOT*, left ventricular outflow tract; *PA*, main pulmonary artery; *RV*, right ventricle; *SVC*, superior vena cava.

usually in the setting of suboptimal transabdominal imaging. All 113 later studies were performed transabdominally.

Early Versus Late FE

Figure 6A documents the frequency with which 2D images of specific cardiovascular structures were obtained in the early versus midgestation fetal echocardiographic examinations. In all but one case, the four-chamber view was obtained and ventricular systolic function qualitatively assessed at both early and later gestational ages. Color and pulsed-wave Doppler studies were performed in all cases, with successful demonstration of specific blood flows and Doppler spectral signals in most (Figures 6B and 6C). Pulmonary venous anatomy by 2D and color and pulsed-wave Doppler interrogation was difficult to demonstrate in the early scans, with improvement in the later studies. This was not true of the remainder of the parameters studied: ≥80% success was achieved for each individual 2D parameter and >90% success for color and ≥74% for pulsed-wave Doppler whether evaluated early or at the standard gestational age.

Complete FE was performed in 27 early (24%; 95% confidence interval [CI], 17%–33%) and 76 later (67%; 95% CI, 58%–75%) exams. If pulmonary vein Doppler assessment was excluded, com-

plete studies were performed in 80 early exams (71%; 95% CI, 62%–78%) and 97 standard midtrimester exams (86%; 95% CI, 78%–91%). Success in performing complete FE exclusive of pulmonary venous Doppler on early FE was 0% at 12 weeks, 50% at 13 weeks, 85% at 14 weeks, 56% at 15 weeks, and 50% at 16 weeks.

Fetal CHD Diagnosis at <17 Weeks

Twenty early fetal echocardiographic studies had abnormal findings: CHD was diagnosed in 14 early exams, functional abnormalities in four, and left-right heart size discrepancy without associated CHD in two. Of the 14 fetuses with CHD, referral indications included suspected abnormality or extracardiac anomaly in five, pregestational diabetes in four, increased nuchal translucency alone in three, abnormal karyotype in one (mosaic trisomy 5), and family history of heart disease in one. Ventricular septal defects were diagnosed in four, tetralogy of Fallot in three, heterotaxy syndrome in two, truncus arteriosus in two, coarctation of the aorta in two, and an atrioventricular septal defect in one. In two patients with tetralogy of Fallot, the family chose termination of pregnancy, and autopsy of the fetus confirmed the echocardiographic findings in both. Functional abnormalities consisted of tricuspid insufficiency in three and pulmonary insufficiency
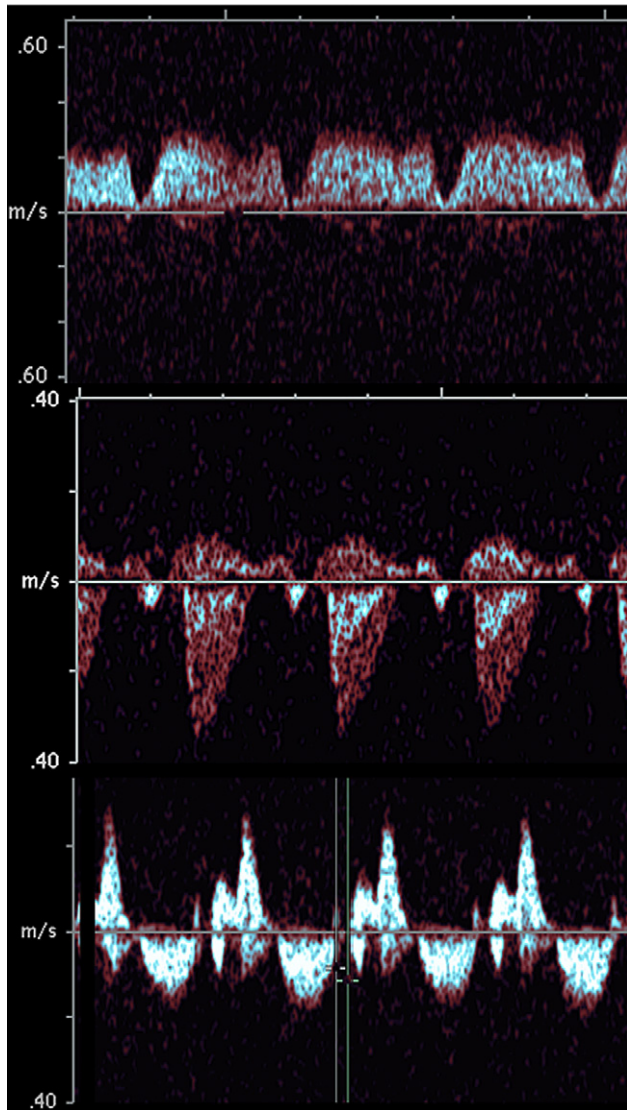
Figure 2 Spectral (pulsed-wave) Doppler waveforms at 13 weeks. (*Top*) Ductus venosus, (*middle*) superior vena cava–aorta, and (*bottom*) left ventricular inflow-outflow (calipers to show isovolumic relaxation time).

in one fetus, none of which had associated structural disease or any other markers of functional abnormality on FE and none of which developed worsening or new findings in follow-up.

Standard FE after 17 weeks confirmed 17 of the 20 "abnormal" early fetal echocardiographic diagnoses. All of the 14 CHD diagnoses were confirmed, with the exception of one of the ventricular septal defects seen on early FE that was not appreciated later. Two of the cardiac functional abnormalities were not seen on the later study, including one fetus each with tricuspid insufficiency and left-right heart size discrepancy. Early FE failed to demonstrate small ventricular septal defects seen on standard FE in three pregnancies (Videos 3 and 4; [available at www.onlinejase.com]). Both early and standard FE missed a small ventricular septal defect in a single patient documented only after birth.

Transvaginal Imaging

Fourteen patients underwent additional transvaginal imaging after the initial attempt at transabdominal imaging. In one normal patient, image resolution with transabdominal transducers was so poor that all of the fetal echocardiographic information was obtained via transvaginal exam; in two other normal fetuses, the four-chamber view was improved sufficiently to allow 2D and color Doppler assessment of individual structures. In two of these three, however, the aortic arch was not seen by either technique. In another three normal patients and one with tetralogy with pulmonary atresia, complete examinations were done with transabdominal transducers, but image resolution was better with the transvaginal probe, and in one patient with tetralogy of Fallot and mild pulmonary outflow narrowing (Figure 7; videos 5 and 6 [available at www.onlinejase.com]), transvaginal examination image resolution was better and allowed 2D visualization of the pulmonary arteries that had not been seen on transabdominal FE. In the remainder, no additional information was scored on the basis of the transvaginal images. In most cases, spectral Doppler images were obtained via the transabdominal approach given the greater range of motion for better angle of insonation, with only one case requiring transvaginal imaging to perform the spectral Doppler examination.

DISCUSSION

In the present study, we have demonstrated that, with the exception of pulmonary venous Doppler interrogation, detailed 2D imaging of cardiac structures, and color and pulsed Doppler interrogation considered standard in a midtrimester exam, can be performed between 12 and 16-6/7 weeks in the majority of pregnancies at risk for fetal CHD. Our early fetal echocardiographic studies were performed using the highest frequency transducers available to delineate the diminutive cardiac structures, higher than what has been reported previously, and most could be performed transabdominally.

Several previous investigators have documented that visualization of cardiac structures, including four chambers, three-vessel view, and origin and crossover of the great arteries, is possible in 90% of pregnancies by 12 to 14 weeks.[12,13] They found transvaginal imaging to be most helpful up to 13 weeks, whereas transabdominal imaging provides sufficient resolution after 13 weeks. Given this previous experience, our own reported experience,[21] and the work of others with successful prenatal detection of cardiac pathology,[17,19] we chose to routinely assess pregnancies at risk for CHD at our institution no earlier than 12 weeks, thus limiting need for reassessment in the late first trimester or early second trimester and the need for transvaginal imaging, not available in many FE programs. We also evaluated the success of imaging for a broader range of early gestational ages, 12 to 16-6/7 weeks, given that standard FE is typically performed after 17 weeks of gestation and, at many institutions, after 18 weeks.

The definition of "complete" FE in our investigation, however, included not only detailed anatomic cardiovascular features in a segmental approach, such as systemic and pulmonary venous connections and ductal and aortic arch position, but also color and pulsed Doppler interrogation of ventricular inflows and outflows, arches, and systemic and pulmonary veins, parameters considered part of complete FE in the standard midtrimester exam on the basis of established guidelines.[22] Color Doppler aids in the identification of flow disturbances, including stenosis and regurgitation, that may not be obvious from interrogation via 2D imaging alone and may help guide placement of the sample volume for spectral Doppler interrogation of both normal and abnormal structures
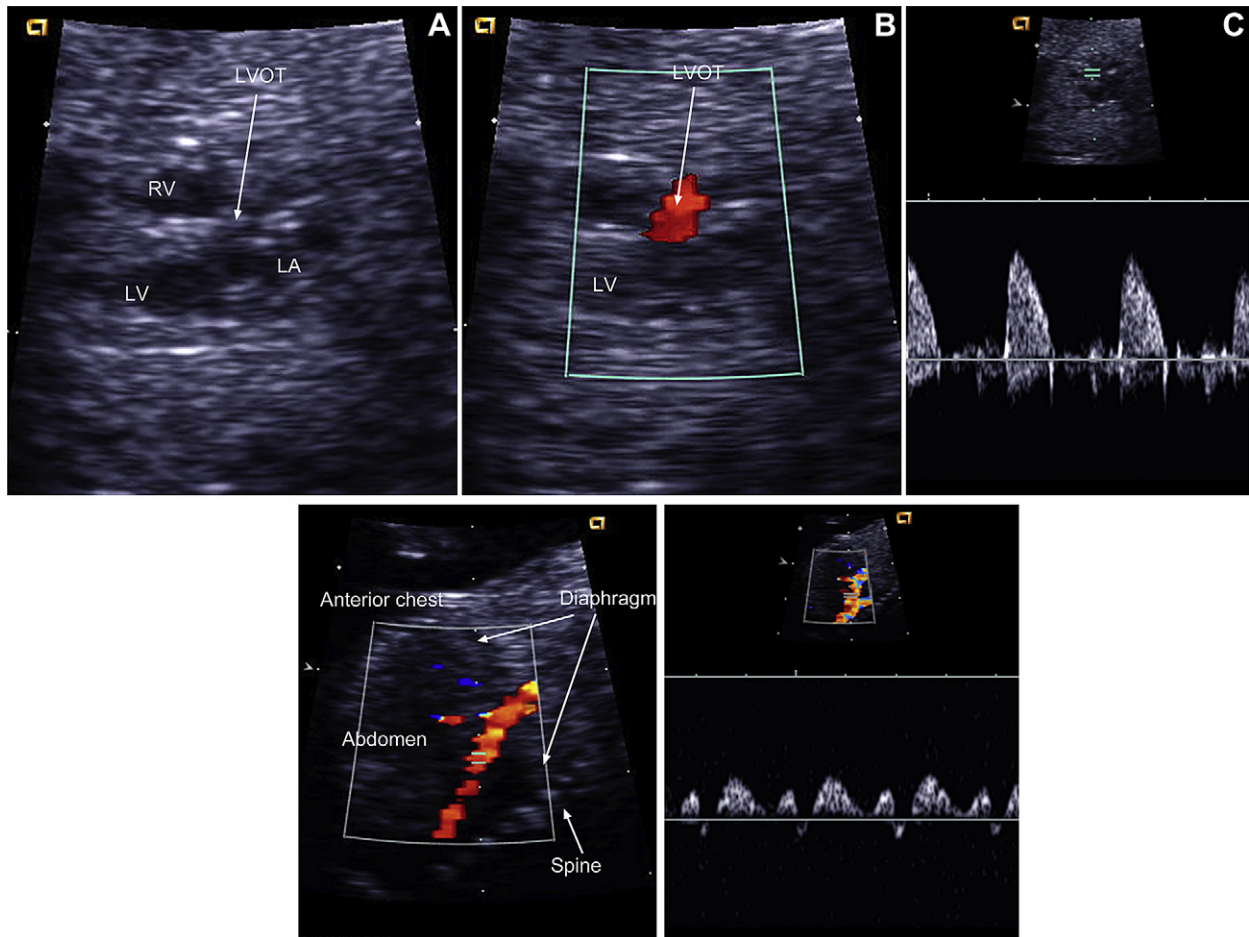
Figure 3 Example of a complete assessment of the left ventricular outflow tract (LVOT) and inferior vena cava via transabdominal imaging with a 10V4 transducer in a fetus at 14 weeks of gestation. (*Top*) **(A)** Two-dimensional anatomy of the left ventricle (LV) in its long axis with the left ventricular outflow, aortic valve, and ascending aorta in the center of the frame, **(B)** with color Doppler, and **(C)** the corresponding spectral Doppler trace. (*Bottom*) Sagittal image of the same fetus with color Doppler demonstrating the hepatic veins and inferior vena cava coursing from the abdomen to the right atrium and the corresponding spectral Doppler trace. *LA*, Left atrium; *RV*, right ventricle.

(Videos 3 and 4; [available at www.onlinejase.com]). Reversal of flow in the ductus arteriosus, signifying significant pulmonary outflow obstruction, for instance, was easily recognized with color Doppler in patients with tetralogy of Fallot, and atrioventricular valve regurgitation was easily identified even in the absence of chamber enlargement; color aided in the identification of septal defects. Pulsed-wave Doppler provides important information regarding both heart rhythm and the hemodynamics of atrial and ventricular contraction, relaxation, and compliance and was useful in the fetuses with right-heart obstruction and those with cardiomyopathy. This detailed assessment is also critical for evaluating fetal CHD severity to provide accurate counseling regarding postnatal management and medical and surgical outcomes.

In the present study, transvaginal imaging was necessary in only 10% of pregnancies, all before 15 weeks, and we observed similar improvement in success rates of complete anatomic imaging with transabdominal scanning after 13 completed weeks. The additional information gained on transvaginal examination was surprisingly limited in our series when transvaginal scanning was used as an adjunct to transabdominal scanning in the same patient. This may have been related at least in part to the fact that our assessments were largely after 12 weeks, and in previous studies, transabdominal imaging at 13 to 14 weeks has been sufficient in the majority of pregnancies.[12,13] Although image resolution was better in many (particularly in at least one fetus with tetralogy of Fallot, allowing precise delineation of the defect), in general, imaging planes are somewhat dependent on fetal lie, given the limited range of movement of the transducer. In addition, imaging may be limited by distance from the transducer to the fetal thorax at older gestational ages, given the higher frequencies used by transvaginal probes, and we observed in a few patients that no additional information was obtained over the transabdominal images. Aortic and ductal arches, in particular, were more likely to be seen via transabdominal imaging. Finally, although not examined in the current series, transvaginal imaging for detailed fetal cardiac assessment may be reserved particularly for gestational ages of <12 weeks, as previously suggested in cardiac screening series.[12,13]

Concerns have been raised about repeated ultrasound examinations during pregnancy.[22] In particular, accessory modalities such as Doppler and tissue harmonics have raised concern. The US Food and Drug Administration has published guidelines regarding the intensity of US used during fetal scanning (Code of Federal
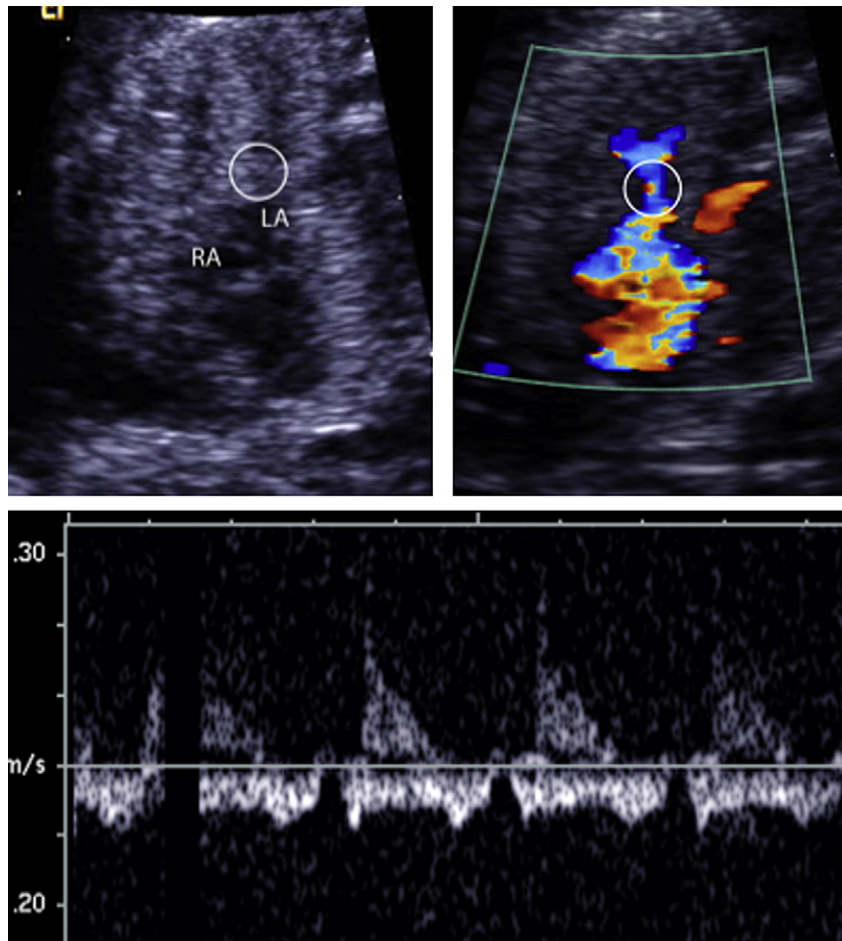
Figure 4 Complete assessment of pulmonary veins in a fetus at 14 weeks of gestation via transabdominal imaging using a 10V4 transducer. Clockwise from upper left, axial four-chamber view showing pulmonary venous connection to the left atrium (LA) (*circled*), with corresponding color Doppler at low Nyquist limit (4 cm/sec), and corresponding spectral Doppler. Note that the Doppler gate has included both the right branch pulmonary artery (*above baseline*) and vein (*below baseline*). *RA*, Right atrium.

Regulations, Title 21, Part 884, Subpart C, § 884.2660). No documented case of fetal injury by clinical ultrasound has been reported. Our standard scanning time for early FE is limited to 25 to 35 min, with limited use of color and spectral Doppler modalities under the principle of "as low as reasonably achievable."

Although in our experience, early FE permitted anatomic and Doppler evaluation of most cardiovascular structures comparable with later FE, assessment of the pulmonary veins to exclude anomalies of pulmonary venous return was more challenging. Two-dimensional imaging of the pulmonary veins was possible in 78% of early exams compared with 91% of later exams. We were able to demonstrate pulmonary venous blood flow through color Doppler and pulsed Doppler in only 33% of early studies compared with 77% of later gestation (standard) FE. Our limited ability to evaluate pulmonary venous blood flow through Doppler interrogation was likely due to the very diminutive nature of the pulmonary veins, limiting their resolution by 2D imaging and rendering placement of the sample volume for Doppler interrogation difficult. Pulmonary venous flow velocities at earlier gestational ages were also very low, well below 10 cm/sec, requiring the use of very low Nyquist limits and reduced filter settings. Since the completion of this investigation, we have found that even when color Doppler interrogation is unable to demonstrate flow in the pulmonary veins, pulsed Doppler interrogation with placement of the sample volume on the basis of the 2D image may result in successful sampling with recorded pulmonary venous Doppler tracings.

Study Limitations

This study was limited in that it represented a retrospective review of available images; anatomic features recognized by the examiner at the time of study but not recorded would necessarily not have been scorable. Additionally, the performers of the echocardiographic studies did not know at the time that their images would be systematically scored and may not have obtained all of the necessary views because of limitations in external factors such as maternal discomfort or fetal activity or in the interest of limiting scan duration, which were not recorded. However, these limitations, had they been addressed in a prospective study, would likely have led to improvements in the completeness of the studies, strengthening our conclusion that early FE can be reasonably complete.

Our study was also limited in that it was a relatively small study and not population based; we evaluated the success of performing complete FE in both the absence and presence of fetal CHD and documented successful diagnosis of abnormalities in 20 of the pregnancies confirmed either later in the midtrimester, postnatally,

Table 1 Two-dimensional and Doppler assessments considered in the evaluation of completeness of early and midtrimester FE

2D anatomic details
Systemic veins (inferior and right and/or left superior vena cavae)
Pulmonary veins (at least one left and one right pulmonary vein connecting with left atrium)
Four-chamber view (both atria, both ventricles, and ventricular septum visualized)
LV outflow (outflow, aortic valve, ascending aorta)
RV outflow (outflow, semilunar valve, main pulmonary artery)
Three-vessel view
Branch pulmonary arteries
Aortic arch (morphology and relationship with trachea)
Ductal arch (morphology and relationship with trachea)
Color Doppler interrogation
Pulmonary veins
LV inflow
RV inflow
LV outflow tract, aortic valve, ascending aorta
RV outflow tract, pulmonary valve, main pulmonary artery
Aortic arch
Ductal arch (ductus arteriosus)
Pulsed Doppler interrogation
Umbilical artery
Umbilical vein
Ductus venosus
Inferior vena cava
Pulmonary vein
RV inflow
LV inflow
RV outflow
LV outflow

LV, Left ventricular; *RV*, right ventricular.

or at autopsy. It is of note that we observed a relatively low incidence of structural CHD (14 of 139 [10%]), for what would normally be considered a population at risk for fetal CHD. Overall, the incidence of moderate and severe forms of CHD among live births is about six in 1,000.[23] The incidence in elevated risk pregnancies varies from 1.18% for pregestational diabetes to 26% for increased nuchal translucency depending on the patient population examined.[24-27] In our study, the majority of patients referred for early FE were from a "lower high-risk" population, predominated by pregestational diabetes or family histories of CHD. Only 16% of patients were referred for increased nuchal translucency, which carries a substantially higher risk for CHD even in the absence of aneuploidy.[8-10,21,24] Therefore, our study was underpowered to demonstrate differences in detection rates of CHD at early versus standard scan times; however, no significant CHD was missed by early FE. In a recent prospective multicenter study in Spain, Comas Gabriel *et al.*[28] detected 40% of fetuses with CHD before 15 weeks. The remainder were diagnosed between 15 and 17 weeks. In addition, FE detected 79.2% of fetuses with CHD in a high-risk population. These findings would suggest that early FE may be quite sensitive for the detection of at least major CHD.

Progression of fetal CHD during the second trimester has been well described.[4,5,29] In particular, outflow obstruction of either ventricle can worsen during this time and become more evident at later gestational ages. Therefore, early FE, even when results are normal, should always be followed by echocardiography at midgestation in patients at high risk for CHD. Although no significant CHD was missed in our study and we were able to perform complete FE in most affected pregnancies, we believe that early FE should not as yet be considered the definitive test, particularly in patients at risk. Additionally, in pregnancies electively terminated after any diagnosis of CHD on early FE, postmortem examination should be encouraged to confirm the cardiac (and extracardiac) diagnoses, which is critical for improving the screens at the earlier gestational ages and counseling regarding the accuracy of the diagnosis as well as risk for future pregnancies. Interestingly, early functional abnormalities (tricuspid regurgitation, pulmonary insufficiency, and right greater than left chamber discrepancy) seen early did not, in this very small number of patients, portend poor outcomes but rather remained stable or normalized with observation. The implications of this are unclear, again given the small number of fetuses studied; further investigation in this area with regard to early fetal cardiac evaluation is necessary.

CONCLUSIONS

Our study shows that nearly complete (exclusive of detailed pulmonary vein interrogation) FE can be performed at 12 to 16-6/7 weeks of gestation in a majority of fetuses at increased risk for CHD. Early FE is most limited in its assessment of pulmonary venous anatomy and blood flow. Most early FE, which includes 2D imaging and pulsed and color Doppler interrogation, can be successfully performed after 12 weeks through a transabdominal approach, with the minority requiring additional transvaginal imaging to complete the evaluation.

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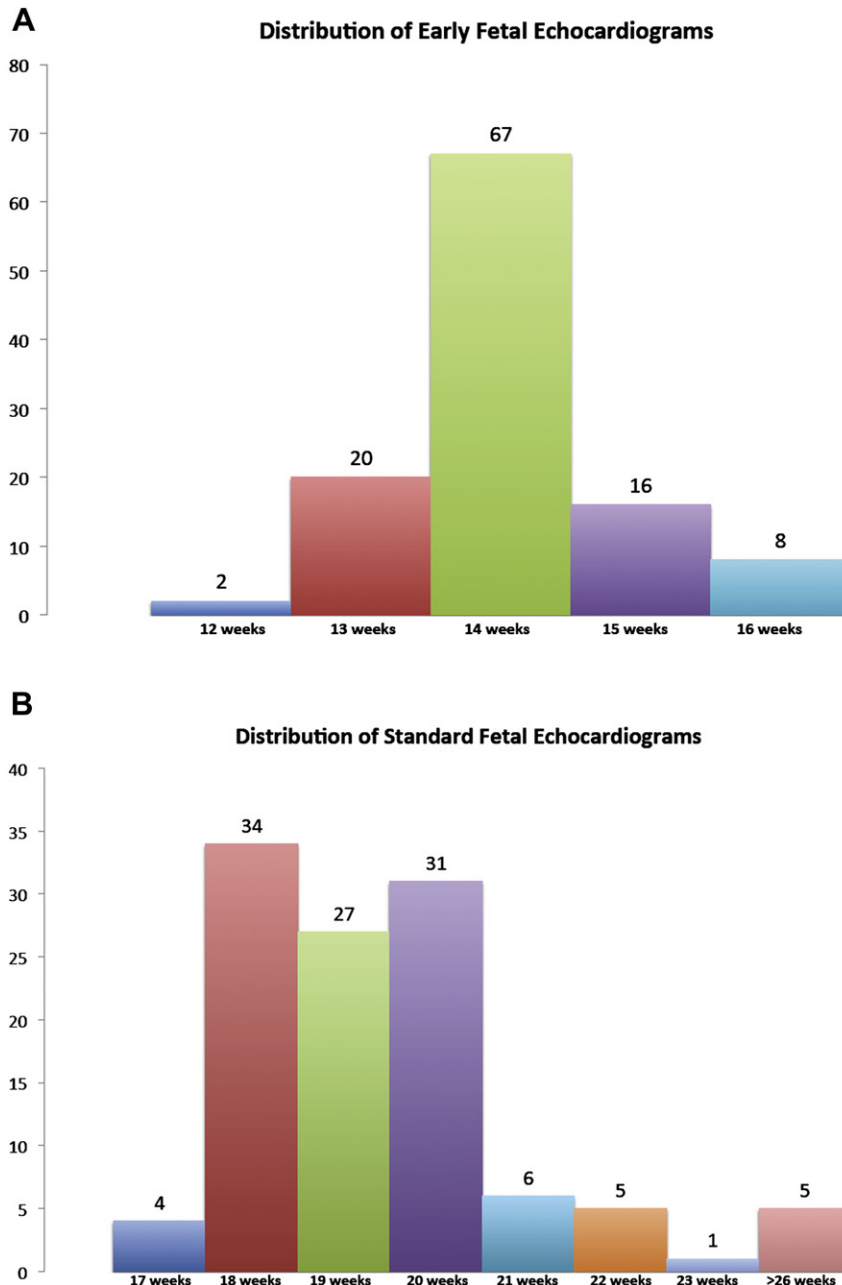29. Allan LD. Evolution of echocardiographic findings in the fetus. Circulation 1997;96:391-2.

A

Distribution of Early Fetal Echocardiograms

B

Distribution of Standard Fetal Echocardiograms

Figure 5 Gestational ages at which the **(A)** early and **(B)** standard midtrimester fetal echocardiograms were obtained as determined by early fetal crown rump length or, when the latter was not available, date of last menstrual period. For each gestational age, the number represents all studied from that gestational age week 0 to +6 days. For example, those studied at 12 weeks of gestation would include 12-0/7 to 12-6/7 weeks.
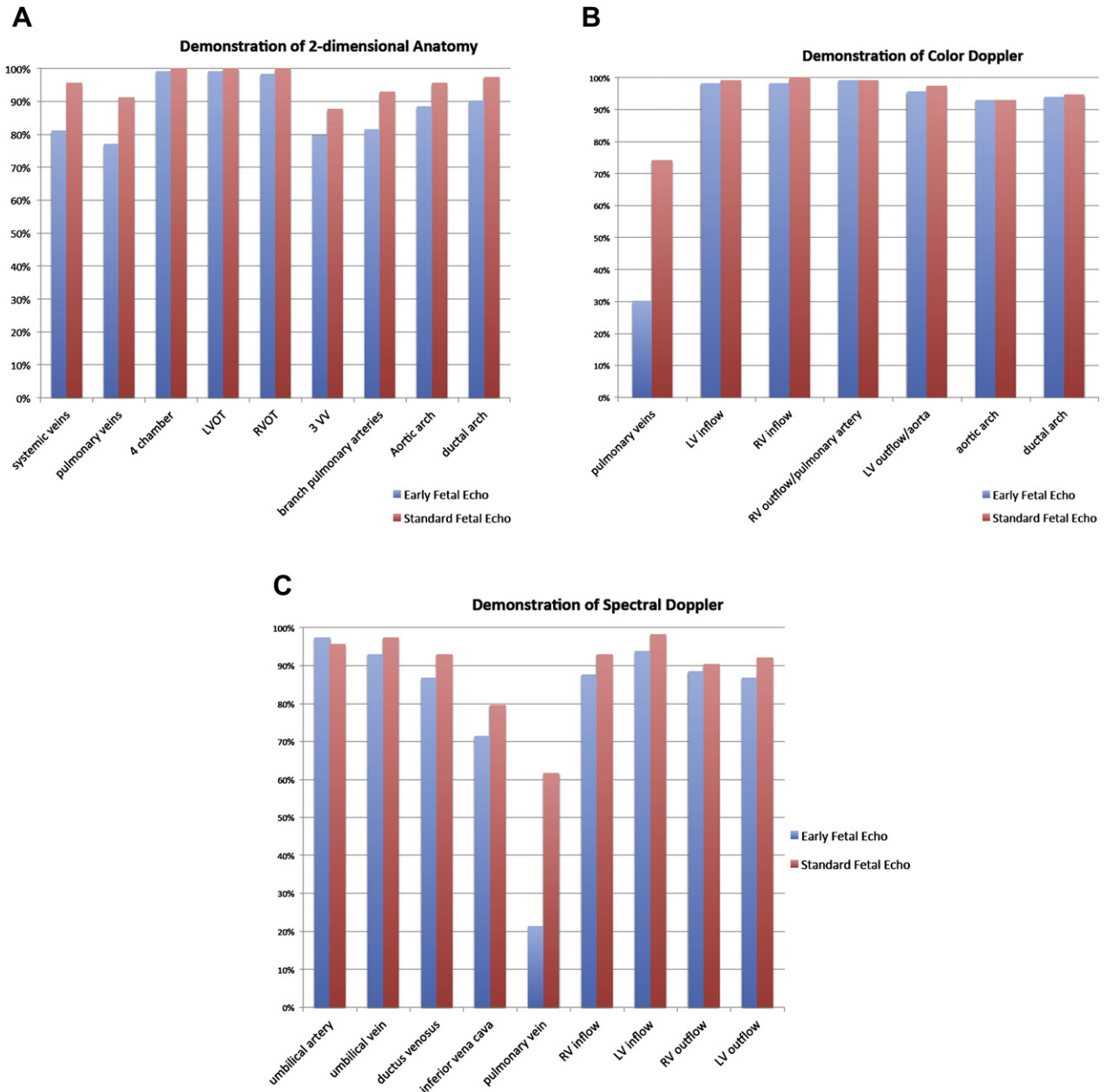
A

B

C

Figure 6 **(A)** Visualization rates for the anatomic features evaluated in both early (*blue*) and standard (*red*) FE. Detection rates are shown as percentages of all studies performed. **(B)** Successful interrogation of specific blood flows by color Doppler. Rates are demonstrated as percentages of all studies performed. **(C)** Successful interrogation of specific blood flows by pulsed-wave Doppler. Rates are again demonstrated as percentages of all studies performed. *LV,* Left ventricular; *LVOT,* left ventricular outflow tract; *RV,* right ventricular, *RVOT,* right ventricular outflow tract; *3 VV,* three-vessel view.
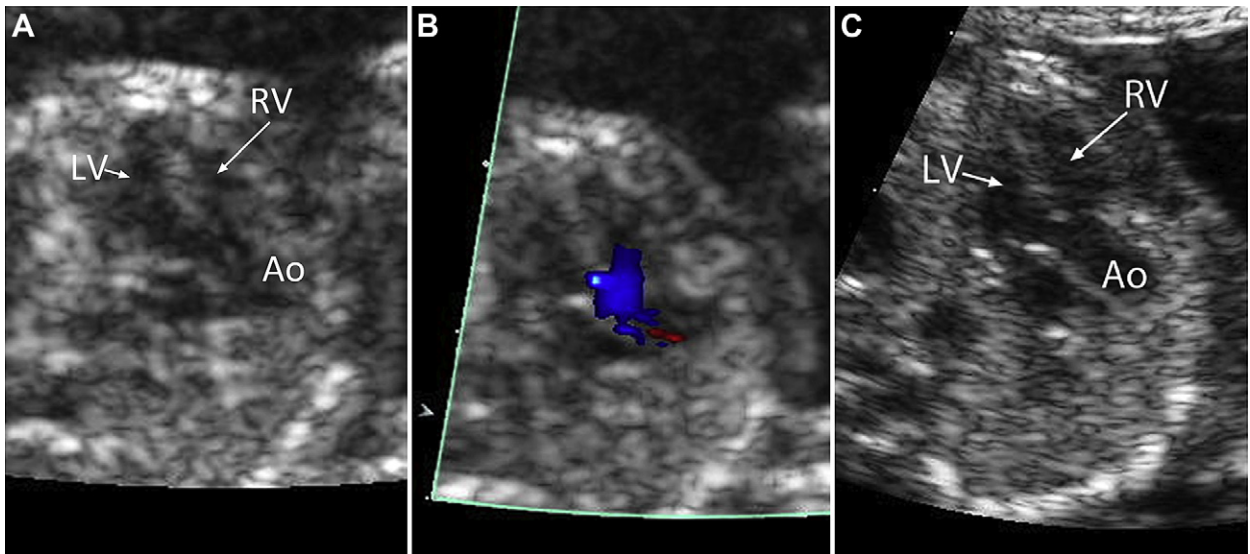
Figure 7 Improved image resolution with endovaginal scanning. In this 15-week fetus with tetralogy of Fallot, the aorta (Ao) is seen overriding a ventricular septal defect using a transabdominal approach (8C4 transducer) **(A,B)**, but the anatomy is more easily seen in **(C)**, via the endovaginal route. Videos 5 and 6 (available at www.onlinejase.com) illustrate cine images corresponding to these still frames. *LV*, Left ventricle; *RV*, right ventricle.