Feasibility of Detection of the 3-Vessel and Trachea View Using 3-Dimensional Sonographic Volumes

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Objectives—The purpose of this study was to investigate the ability to depict the 4-chamber and 3-vessel and trachea views of the fetal heart using 3-dimensional sonography.

Methods—Three-dimensional color Doppler volumes of the fetal heart were acquired prospectively in 31 fetuses between 19 and 25 gestational weeks. The initial plane consisted of the 4-chamber view. Postprocessing included navigation within the volume solely in plane A in the caudal direction to visualize the stomach and in the cephalic direction to the plane of the 3-vessel and trachea view to visualize the pulmonary artery, the aorta, the V shape and color of the arches, the superior vena cava, and the trachea. The feasibility of showing these organs was evaluated.

Results—The estimated time for volume acquisition and manipulation was about 60 seconds. The detection rates for the 4-chamber view, stomach, 3-vessel view, trachea, and V sign were 100%, 93.5%, 92.0%, 77.4%, and 83.9%, respectively, with interobserver agreement of 0.76 to 1.0.

Conclusions—We describe a simple technique in which a single sweep on 3-dimensional sonography starting at the level of the 4-chamber view can visualize the situs, stomach, 4-chamber view, and transverse view of the outflow tracts of the heart.

Key Words—fetal heart; obstetric ultrasound; outflow tracts; 3-dimensional sonography; 3-vessel and trachea view

Prenatal diagnosis of congenital heart disease is of great importance because of its high birth incidence and the increased risk of neonatal mortality. Anatomic abnormalities of the fetal heart remain difficult to diagnose prenatally because of the high degree of expertise required for a thorough cardiac examination, with only one-third of major congenital heart defects detected before birth.[1–3] Depiction of the 4-chamber view and the outflow tracts is necessary for a complete fetal cardiac assessment.

Two-dimensional (2D) sonography is highly dependent on the skills and experience of the operator. The reported 2D sonographic depiction of the 4-chamber view ranged from 91% to 98%,[3–5] and the satisfactory depiction of the outflow tracts was reported to be 40%, with a long learning curve.[3] The use of 4-dimensional sonography has been shown to enable operators to navigate within the volume and view the heart from different angles at the same time using sagittal, axial, and coronal planes, thus facilitating visualization of standard cardiac diagnostic planes, with greater than 80% depiction of the outflow tracts.[5–13] Since 3-dimensional (3D) sonog-

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Abbreviations
3D, 3-dimensional; 2D, 2-dimensional

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raphy is more available and easier to learn than 4-dimensional sonography, our objective was to find an algorithm using 3D sonography to facilitate the examination of the fetal heart. The aim of this study was to investigate the ability to depict the 4-chamber and 3-vessel and trachea views of the fetal heart using 3D sonography.

Materials and Methods

A prospective study of uncomplicated consecutive pregnancies was conducted. The following inclusion criteria were used: singleton pregnancies, normal anatomic scans, adequate-for-gestational age fetuses, and no maternal illnesses or complications of pregnancy (ie, preeclampsia or diabetes). Gestational age was determined by the last menstrual period and confirmed by crown-rump length measurement in the first trimester.

Three-dimensional volumes of the fetal heart were acquired at the time of routine sonographic examinations after acceptance of informed consent. Approval was granted by the Institutional Review Board of the Chaim Sheba Medical Center. Complete anatomic scans were performed.

Technique

Volumes of the fetal heart were acquired by using 3D software with color Doppler imaging in the axial plane at the level of the 4-chamber view. Examinations were done with Voluson 730 Pro, 730 Expert, and E8 ultrasound machines (GE Healthcare, Kretz Ultrasound, Zipf, Austria) using volumetric abdominal RAB4-8 transducers. The 3D volumes were taken during conventional scanning while examining the fetal heart. The standard volume sweep angle was 55°, and when color Doppler imaging was performed, the angle of acquisition was 45°. The angle of acquisition was manipulated to include the whole fetal heart, according to the gestational age and the distance of the fetal heart from the transducer. We used speckle-reduction imaging[2] and cross-beam imaging[1] in the cardiac sonographic preset. The color Doppler preset included moderate quality and low frequency. The pulse repetition frequency was adjusted to fill the ventricles with minimal artifacts.

Acquisitions were performed by a single sonographer (L.G.) during fetal rest and absence of fetal movements. Offline analysis and postprocessing were performed with 4D View software (GE Healthcare, Kretz Ultrasound). All volumes were analyzed offline by 2 experienced examiners separately (A.W.-B. and M.Z.). The feasibility of identifying the fetal 4-chamber and 3-vessel and trachea views was analyzed.

Three-dimensional volumes of the fetal heart were acquired when depiction of the 4-chamber view in the axial plane with color Doppler imaging was optimal. The optimal fetal position was with the cardiac apex anterior, trying to avoid acoustic shadows (Figure 1A). When the fetal position was not optimal, volumes were acquired obliquely or from another position in which the 4-chamber view could be visualized.

Postprocessing of the acquired volume included navigation within the volume solely in plane A (axial plane of the fetus) in 2 directions: caudal to visualize the stomach and cephalic to identify the plane of the 3-vessel and trachea view to visualize the aorta (Figure 1B), the pulmonary artery (Figure 1C), the V shape and color of the arches, the superior vena cava, and the trachea (Figure 1D and Videos 1 and 2). The feasibility of depicting those structures was evaluated.

Statistical Analysis

Data were analyzed with SPSS version 11.5 software (IBM Corporation, Armonk, NY). Comparison of means was done by an independent *t* test. $P < .05$ was considered significant. Correlations were analyzed by 2-tailed Pearson correlation and presented as linear regression with a 95% prediction interval. Interobserver agreement was analyzed by κ statistics.

Results

Thirty-one fetuses constituted the study population. Gestational ages ranged from 19 weeks 4 days to 25 weeks (median, 22 weeks 4 days). The estimated time for volume acquisition and manipulation in plane A was approximately 60 seconds. All neonates underwent a thorough pediatric evaluation after delivery, which yielded normal findings with no congenital cardiac anomalies.

Table 1 shows the detection rates and interobserver agreement for the 4-chamber view, stomach, 3-vessel view, trachea, and V sign by the postprocessing examiners. In 13 of 31 examinations (42%), acquisitions were made in the axial frontal view. Complete detection of all anatomic landmarks (stomach, 4-chamber view, 3-vessel view, trachea, and V sign) occurred in 74% of examinations (90% with the fetus in the frontal position and only 55% when acquisition was not made in the frontal position; $P = .031$).

Visualization of the stomach (24 of 26 versus 34 of 36, for frontal and nonfrontal views, respectively; $P = .76$) and 4-chamber view (26 of 26 versus 36 of 36) were not related to the initial plane during acquisition. Visualization of the 3-vessel view (26 of 26 versus 31 of 36; $P = .05$), trachea

(24 of 26 versus 24 of 36; $P = .01$) and V sign (26 of 26 versus 26 of 36; $P = .002$) were associated with the initial plane of acquisition. The V sign with color was identified in 74% of patients but was not associated with the initial view (20 of 26 versus 26 of 36; $P = .67$).

Discussion

This article describes a simple, novel technique in which a single sweep on 3D sonography with color Doppler imaging, starting at the level of the 4-chamber view, can visualize the situs, stomach, 4-chamber view, and transverse view of the outflow tracts of the heart. The estimated time for volume acquisition and manipulation was about 60 seconds. Although other investigators have tried similar techniques using grayscale imaging[14] and special temporal imaging (spatiotemporal image correlation)[12] our study showed these views in a simple maneuver with no need for extensive postprocessing manipulations.

A fetal cardiac examination poses a challenge to the sonographer, and our goal was to simplify the cardiac examination. Therefore, we navigated solely in plane A of the sectional planes. We aimed to depict the axial views of the fetal heart. We did not aim to manipulate the volume and depict the sagittal view of the outflow tracts. That process would be difficult with 3D sonography, since movement of the heart creates zigzag images on the B and C planes. Previous studies have demonstrated that navi-

Figure 1. **A**, Initial image of a volume at the level of 4-chamber view in a fetus at 23 gestational weeks. This view is an axial plane in which the fetal spine is posterior. LA indicates left atrium; LV, left ventricle; RA, right atrium; and RV, right ventricle. **B**, Left ventricular outflow tract in the same volume. A slightly cephalic axial plane shows the aorta coming out of the left ventricle, which is seen in a nearly perpendicular direction to the 12- to 6-o'clock plane through the thorax. **C**, Right ventricular outflow tract in the same volume. An axial plane slightly cephalic to **B** shows the main pulmonary artery arising from the right ventricle. At this level, the pulmonary valve can be depicted by turning off the color during postprocessing. The right pulmonary artery and ductus arteriosus are also shown at this level. Notice that color may not fill the entire vessel, as it depends on the angle of acquisition. **D**, Three-vessel and trachea view in the same volume. An axial plane slightly cephalic to **C** shows the arches of the great arteries. From left to right, the ductal arch, aortic arch, trachea, and superior vena cava (SVC) are shown, creating the color V sign. Blue indicates that blood flow is moving toward the descending aorta.

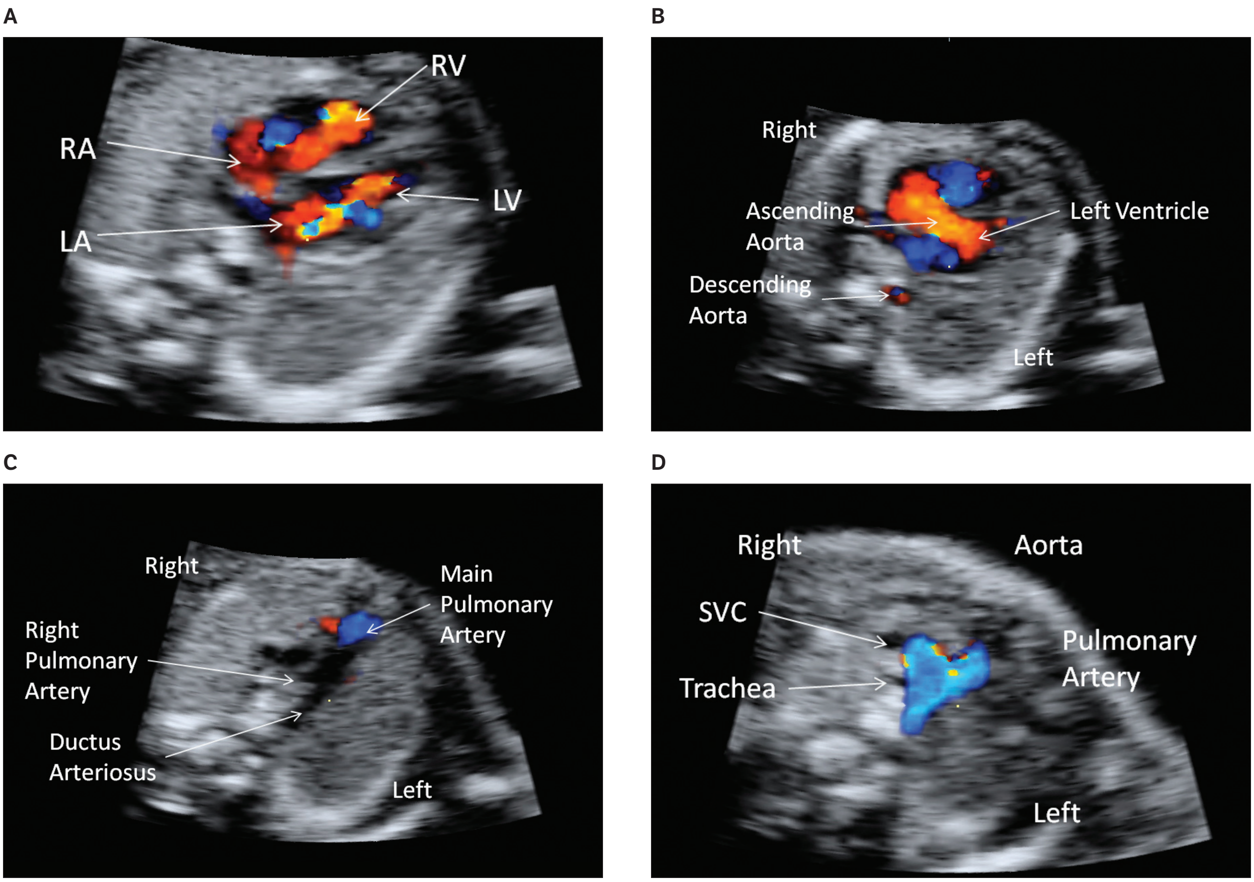

Table 1. Detection Rates for the Different Cardiac Views

View	Observer A, n (%)	Observer B, n (%)	κ
Stomach	29/31 (93.5)	29/31 (93.5)	1.0
4-Chamber	31/31 (100)	31/31 (100)	NA
3-Vessel	29/31 (93.5)	28/31 (90.3)	0.78
Trachea	25/31 (80.6)	23/31 (74.2)	0.82
V sign	27/31 (87.1)	25/31 (80.6)	0.76
Color in V sign	24/31 (77.4)	22/31 (71.0)	0.83

NA indicates not applicable.

gation within all sectional planes facilitated evaluation of the axial and sagittal views of the heart and, in particular, the outflow tracts,[8,15] but that procedure takes additional training and experience.

Views of the fetal heart were suboptimal when the fetal chest faced down with the spine up, causing acoustic shadows. Indeed, the limitation of this method also applies to 2D sonography and is primarily related to dependence on the fetal position and maternal body habitus for optimal imaging. No data regarding the maternal body mass index were taken. Further studies are needed to compare the duration and the ability to optimally scan patients with regard to their body mass index on both 2D and 3D sonography.

The addition of color Doppler imaging aided in the evaluation of the 4-chamber view, the position and organization of vessels in the 3-vessel and trachea view, the direction of flow in the aorta, pulmonary artery, and superior vena cava, and the sizes of the great vessels (ie, the pulmonary artery should be slightly larger than the aorta [1.3 times], and the aorta should be larger than the superior vena cava).[16–18] In routine practice, the 3-vessel and trachea view and the V-sign are not always depicted by all sonographers, and our technique simplifies their detection. These views are important for estimation of the fetal heart regarding the number of vessels, their size, and their alignment.

The objective of our study was to present an alternative method to depict the important 3-vessel and trachea view. Our goal was not to compare our technique to other techniques used to examine the fetal heart but to provide another tool for the sonographer to facilitate depiction of the fetal heart. Not all sonographers depict the 3-vessel and trachea view in their common practice while they use the 2D sweep technique. In our expert hands, we depicted the 3-vessel and trachea view in all of our patients. The simple method we present requires the basic skills of identifying the 4-chamber view. The main advantage of the technique is assisting sonographers who fail to depict the 3-vessel and trachea view by the 2D sweep. Another advantage is the ability to use this simple technique for teaching and acquiring sonographic skills.

In conclusion, we have described a simple method for evaluating the stomach, 4-chamber view, 3-vessel and trachea view, and V sign during a regular anatomic scan and have shown that it is feasible in the clinical setting. Basic knowledge of 3D sonography along with good depiction of the 4-chamber view allows an easy extension of the cardiac examination to the 3-vessel and trachea view in more than 90% of cases. Information about the number of vessels, shape, diameter, direction of flow, and relationship of the two arches is achieved by this simple sonographic method. Adding this short, simple technique to the sonographic anatomic scan may facilitate and improve 2D sonographic evaluation of the fetal heart.

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