

The role of 3D ultrasonography in the analysis of fetal cardiac anatomy

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Abstract

Objective: We aimed in this study to compare two-dimensional ultrasonography with three-dimensional ultrasonography for obtaining standard anatomic cross-sections used during ultrasonographic fetal cardiac examination between 18 and 24 weeks of gestation.

Methods: Four-chamber view, aorta, pulmonary arterial outlets and cross-section of three-vessel in real-time gray scale were obtained from totally 2839 patients between 18 and 24 weeks of gestation who referred to the Obstetrics and Gynecology Clinic of Mersin University's Health Practices and Research Hospital between 16.01.2007 and 19.12.2009, and were admitted for fetal anatomic screening. Subsequently, they were evaluated according to the protocol defined by obtaining static three-dimensional volume data.

Results: Totally 2839 pregnant women who were between 18 and 24 weeks of gestation with ages between 18 and 43 were included into the study. The median age was 27.3 (range: 17-46) years, mean pregnancy number was 1.9 (range: 1-7), and mean examination week was 21 weeks and 4 days. In the evaluation, congenital anomaly was found in 143 cases (5.03%), and among them, congenital cardiac anomaly was in 28 cases (0.9%). Four-chamber views were obtained in all cases whose volume data were taken by 3D ultrasonography. Seventy-eight percent of aortic outlet was observed, 75% of pulmonary outlet was observed and 90% of vessels and trachea cross-section was observed.

Conclusion: It was observed that the standard cross-sections consulted during fetal cardiac examination by 3D ultrasonography were obtained with a rate between 75-90%. On the other hand, technical issues we faced during conventional ultrasonographic evaluation prevented also by this method to yield satisfactory results during the examination.

Key words: Fetal heart, three-dimensional evaluation, four-chamber view, cross-section of three-vessel, examination at 18-23 weeks of gestation.

Fetal kardiyak anatomisinin değerlendirilmesinde üç boyutlu ultrasonografinin yeri

Amaç: Bu çalışmada 18-24. gebelik haftaları arasında ultrasonografi ile fetal kardiyak muayene sırasında başvurulanan standart anatomik kesitlerin elde edilmesinde; iki boyutlu ultrasonografi ile 3 boyutlu ultrasonografiyi karşılaştırmayı amaçladık.

Yöntem: 16.01.2007 - 19.12.2009 tarihleri arasında Mersin Üniversitesi Sağlık Uygulama ve Araştırma Hastanesi Kadın Hastalıkları ve Doğum polikliniğine başvuran, 18-24. gebelik haftaları arasında bulunan ve fetal anatomik tarama için kabul edilen toplam 2839 hastada önce 4 oda, aort, pulmoner arter çıkışları ve 3 damar kesitleri gerçek zamanlı gri skala görüntülerle elde edildi. Bunu takiben statik 3 boyutlu hacim verileri alınarak tanımlanan protokole göre değerlendirildi.

Bulgular: Yaşları 18-43 arasında değişen toplam 2839 gebe 18-24. gebelik haftaları arasında değerlendirildi. Olguların medyan yaşları 27.3 (dağılım: 17-46), ortalama gebelik sayıları 1.9 (dağılım: 1-7), ortalama değerlendirme haftası 21 hafta 4 gündü. Yapılan değerlendirmede, toplam yakalanan konjenital anomali sayısı 143 (%5.03), bunlar içinde konjenital kalp anomali yakalananların sayısı 28 (%0.9) idi. Üç boyutlu ultrasonografi ile hacim verileri (volume data) elde edilen olguların tamamında 4 odacık görüntüsü elde edildi. Aort çıkışı %78, pulmoner çıkışı %75, 3 damar-trakea kesiti ise %90 elde edildi.

Sonuç: Üç boyutlu ultrasonografi ile fetal kardiyak muayenede başvurulanan standart kesitlerin %75-90'lar arasında değişen oranlarda elde edildiği izlendi. Öte yandan konvansiyonel ultrasonografik değerlendirilmede önümüze çıkan teknik koşulların bu yöntemde de muayene sırasında tatminkar sonuçların elde edilmesini etkilediği gözlemlendi.

Anahtar sözcükler: Fetal kalp, 3 boyutlu değerlendirme, 4 odacık görüntüsü, 3 damar kesiti, 18-23. gebelik haftası muayenesi.

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Introduction

Fetal cardiac anomalies are observed approximately in one of each one hundred pregnancies.^[1,2] Fetal cardiac anomalies are still responsible for 20% of perinatal mortality.^[2] Therefore, diagnosing congenital cardiac anomalies within the context of prenatal diagnosis and screening, presenting accompanying structural anomalies and genetic problems, predicting prognosis by determining those who had postnatal treatment and terminating pregnancy medically if necessary are of crucial importance.^[3] Major factors causing difficulty in screening and diagnosis can be enumerated as the complex embryonal development that heart undergoes, movements and position of fetus, amniotic fluid index, technical limitations of conventional two-dimensional ultrasonography devices and the conditions arising from operators. Another significant issue in the evaluation of fetal heart and the diagnosis of cardiac anomalies is the multi-planar evaluation requirement.^[4,5] Therefore, collecting images used in the diagnosis as volume data or ability to review again by using appropriate software later ensures effective use of ultrasonography in diagnosis.^[6,7] At the same time, sharing and consultation of raw volume data with a remote and more experienced colleague via Internet are one of the significant goals for the future. Three-dimensional or real-time 3D ultrasonography (4D evaluation) enables to make multi-planar evaluation of heart like any other anatomic organ, and to store obtained data for further re-evaluations.

In this study, we aimed to compare two-dimensional ultrasonography with three-dimensional ultrasonography for obtaining standard anatomic cross-sections to use in the evaluation of fetal heart at second trimester.

Methods

For this project, a total of 2839 patients between 18 and 24 weeks of gestation, who referred to the Obstetrics and Gynecology Clinic of Mersin University's Health Practices and Research Hospital between 16.01.2007 and 19.12.2009 and were admitted for fetal anatomic screening, were examined by Philips HD-11 XE ultrasonography device (Philips Healthcare, Best, The Netherlands) with 4-8 MHz convex volume probe according to the protocol defined below. All ultrasonographic examinations were carried out by a single operator (TUKD). Cases suspected to have cardiac anomaly was referred to pediatric cardiology department, and the diagnosis was confirmed.

Study Protocol

While on supine position and the bladder was empty, the fetus was evaluated by using 4-8 MHz convex volume probe on the patient transabdominally.

During the procedure, it was paid attention that the fetal vertebra was away from the probe and the fetus was on supine position, preferably in immobile period.^[8] In the standard 2D evaluation by transverse incision, sweep technique defined by Yagel et al.^[9] was used and four quadrants, outlet and crossing conditions of major vessels, and three-vessel and trachea cross-section were evaluated.

Subsequently, the cross-sections were evaluated by carrying out rotations on X, Y and Z planes and sliding section by section on three-dimensional static image with 45° sweep angle and by obtaining static 3D volumes (**Figs. 1 and 2**). Each patient was evaluated by single operator at least for 20 minutes. The cases diagnosed with fetal cardiac anomaly were referred to a pediatric cardiology expert.

Statistics

The data was analyzed by SPSS 11.0 (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA). Among central distribution criteria, the median values were used for the data not displaying normal distribution, and the mean values were used for those displaying normal distribution.

Results

A total of 2839 pregnant women with ages between 18 and 43 were evaluated between 18 and 24 weeks of gestation. The median age of the cases was 27.3 (range: 17-46) years, median number of pregnancy was 1.9 (range: 1-7), and mean evaluation week was 21 weeks and 4 days. In the evaluation, congenital anomaly was found in 143 cases (5.03%), and among them, congenital cardiac anomaly was in 28 cases (0.9%). There was no case which could not be diagnosed by 2D ultrasonography but could be diagnosed by 3D ultrasonography.

When the methods were compared, 3D images could not be obtained for position, fetal movements, oligohydramnios, maternal obesity, and because of previous multiple abdominal surgery in approximately 25% of the patients. Four-chamber view was obtained in all cases of whom sufficient amount of images were obtained by 3D ultrasonography (those who did not dis-

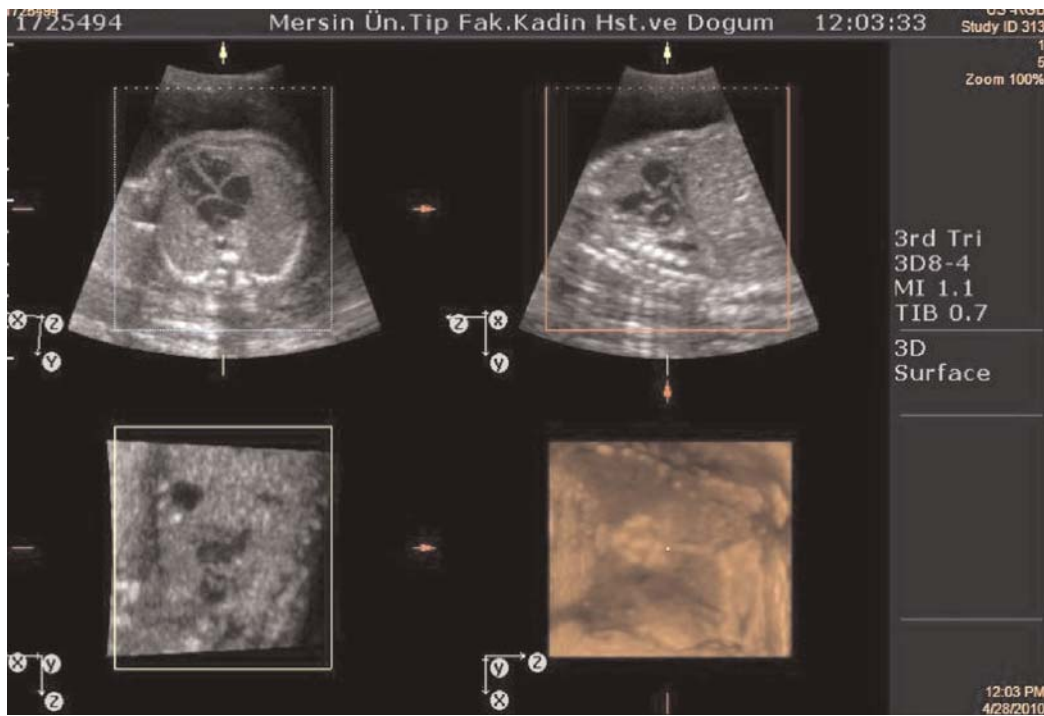


Fig. 1. Four-chamber view on the images taken by 3D ultrasonography data set.

play any artifact due to fetal movement). Seventy-eight percent of aortic outlet, 75.3% of pulmonary outlet, and 90% of vessels and trachea cross-section were obtained.

Congenital cardiac anomalies diagnosed and their distributions are shown in the **Table 1**.

Discussion

Congenital cardiac diseases are the most common malformations seen in 0.8% of live births, and at least half of them result in death and require surgical intervention. They are responsible for 30% of perinatal mortality. They are observed 6 times more than chromosomal anomalies and 4 times more than neural tube defects.^[2] Becoming possible to image fetus ultrasonographically at the end of 1970s, evaluation of fetal heart was included into the obstetric examination.^[10] Although there were various conventional techniques used in the evaluation of fetal heart, the common goals of all techniques include revealing cardiac situs and position, determining the structures and localizations of chambers and valves, and revealing atrioventricular-ventriculoarterial relationships.

Main limitations of the evaluation of fetal heart by conventional 2D ultrasonography are caused by fetal position, amniotic fluid amount and gestational factors. Additionally, operator habits and limited number of qualified experts are also significant obstacles. Ventricle, revealing major vessel relationships, and displaying spatial relationships of aorta and pulmonary artery require multiplanar evaluation. The requirement for multiplanar evaluation and revealing spatial relationships independent from operator, and the need for further re-evaluations by storing obtained data made it necessary to use 3D ultrasonography with different technical modalities.

The rate to obtain standardized planes used in the classical 2D evaluation of 3D ultrasonography has been evaluated by various studies. Levental et al.^[10] observed the four-quadrant view, right ventricular outlet and left ventricular outlet 100%, 42% and 71%, respectively in the 2D evaluation while they were 71%, 6-26% and 13-45%, respectively in the 3D evaluation. Zosmer et al.^[11] showed the cross-section of 4 quadrants in 85%, aortic outlet in 87% and pulmonary outlet in 57%. Bega et al.^[12] observed aortic outlet 87% (which was 68% in 2D technique), and the tractus of pulmonary outlet 100% (which was 68% in 2D) by 3D ultrasonography. While the mean

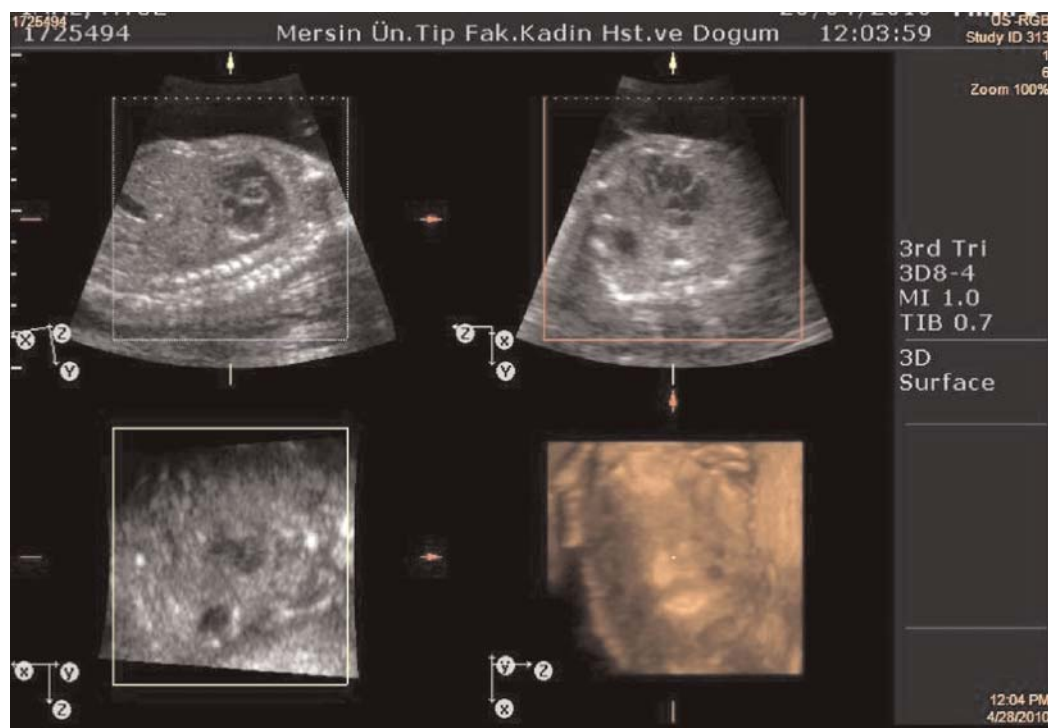


Fig. 2. Pulmonary aortic outlet on parasagittal plane on the images taken by 3D ultrasonography data set.

duration for obtaining cross-sections was 2 minutes and 43 seconds in the standard technique, it was 2 minutes and 50 seconds in the 3D evaluation.^[13] In our study, we were able to obtain four-chamber view in all cases in which sufficient images were obtained by 3D ultrasonography. Aortic outlet was 78%, pulmonary outlet was 75.3%, and vessel and trachea cross-section was 90%. These rates are similar to the results reported above.

Three-dimensional fetal echocardiography, especially STIC (spatio-temporal image correlation) becoming popular in the centers contains many questions not clarified yet. While Chaoui et al.^[6] obtained cardiac data which constituted basis for STIC in 95% of the cases evaluated, Rizzo et al.^[14] reported the rate varying between 70% and 90%. Sending the obtained data to specialists via Internet who are expert on fetal echocardiography and their analyses are another topic dwelled on. The capability of sonographer or obstetrician and his/her contribution on the process is also a significant issue questioned as well as the method used for obtaining data. Vinals et al.^[15] showed that obstetricians exercising general practice were able to collect 94-96% of required data set while Paladini et al.^[16] reported that

sonographers who have no further experience other than standard qualifications on the evaluation of heart were able to collect 66-100% of required data after 2-hour training. Vascular relationships can be better presented by adding modalities such as TUI (tomographic ultrasound imaging) and/or B-flow into the diagnosis of complex cardiac anomalies except screening.^[17,18]

Determining how much 3D ultrasonography contributes to the conventional ultrasonography for the diagnosis of fetal cardiac anomalies is another question

Table 1. Diagnosed cardiac anomalies and their distribution.

Anomaly	Number (%)
VSD	14 (50)
Truncus arteriosus	4 (14.28)
Hypoplastic right heart	3 (10.7)
Fallot's tetralogy	2 (7.14)
ASD	2 (7.14)
Hypoplastic left heart	1 (3.57)
Ectopia cordis	1 (3.57)
AVSD	1 (3.57)
Total	28 (0.9)

to answer. Yagel et al.^[19] analyzed 13,101 evaluations prospectively, and observed that 3D and 4D ultrasonographic evaluations provided additional data in 12 cases among 181 cases diagnosed with congenital cardiac disease. According to this study, 3D and 4D ultrasonographic evaluations provide additional contribution to the diagnosis in 6% of cases evaluated.

In our study, we observed that 3D ultrasonography for obtaining standard anatomic cross-sections was affected by technical conditions such as fetal position and immobility. Technical conditions required for standard ultrasonographic evaluation such as proper fetal position, maternal body mass index, history of operations undergone, localization of placenta and amniotic fluid are also the minimum conditions required for 3D evaluation.

Conclusion

It should be kept in mind that three-dimensional ultrasonography and complementary methods have an advantage over classical 2D ultrasonography due to the possibility of multiplanar evaluation of especially major vessel anomalies and venous systems. However, its contribution the diagnosis of fetal cardiac anomalies and its role in patient management should be presented by prospective studies.

Conflicts of Interest: No conflicts declared.

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