Prenatal echocardiographic diagnosis of cardiac right/left axis and malpositions according to standardized Cordes technique

Standart Cordes tekniğine göre kalbin sağ/sol ekseninin ve malpozisyonlarının prenatal ekokardiyografik tanısı

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ABSTRACT

Objective: The aim of this study was to evaluate distinguishing the right / left side of the fetus, cardiac axis and position according to the standardized Cordes technique in 20 cases with cardiac malposition.

Methods: We studied retrospectively 1536 cases whose fetal echocardiographic examinations were performed between 1999 and 2006 in prenatal cardiology unit. Among these, cardiac malpositions were determined in 20 cases. The cardiac axis and position were determined according to the Cordes technique. All cases were followed-up by serial fetal echocardiograms until birth or intrauterine death occurred. In cases of intrauterine death, an autopsy was performed. After birth, physical and echocardiographic examinations were done and prenatal and postnatal diagnoses were compared.

Results: Of 1536 fetal echocardiograms performed, 144 revealed congenital heart diseases (9.4%), among these cases 20 were diagnosed with cardiac malposition. Of cases with cardiac malposition, 16 had congenital heart disease, and four had extracardiac malformation. There were six cases of isolated dextrocardia, three cases of *situs inversus totalis*, six cases of *situs ambiguous*, and one case of *situs inversus* with isolated levocardia. Of four cases with extracardiac malformations, two cases had mesoposition, one had dextroposition, and one had extreme levoposition. In six cases the autopsy findings were the same as that their prenatal echocardiographic findings. When postnatal echocardiographic results of the remaining cases with cardiac malposition due to congenital heart disease were compared with prenatal diagnoses, the same echocardiographic findings were verified.

Conclusion: The fetal right/left axis must be determined correctly for the accurate diagnosis of cardiac malpositions. Therefore, we recommend that Cordes technique provides a simple and reliable determination of the fetal right/left axis and fetal *situs*.
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Key words: Fetal echocardiography, fetal *situs*, fetal cardiac malposition, dextrocardia, *situs ambiguous*, Cordes technique

ÖZET

Amaç: Bu çalışmada, standart Cordes tekniğine göre fetüsün sağ/sol tarafının, kalbin aksının ve pozisyonunun ayrımı ve bu teknikle kardiyak malpozisyon tanısı konulan 20 olgunun değerlendirilmesi amaçlandı.

Yöntemler: Çalışmamızda, 1999-2006 yılları arasında prenatal Kardiyoloji ünitesinde fetal ekokardiyografi yapılan 1536 olguyu retrospektif olarak değerlendirildi. Bu olguların 20'sinde kardiyak malpozisyon saptandı. Kalbin aksı ve pozisyonu Cordes tekniğe göre saptandı. Tüm olgular seri fetal ekokardiyografik çalışmalar ile doğuma veya intrauterinde ölüm meydana gelene kadar izlendi. İntrauterin ölen olgulara otopsi yapıldı. Doğumdan sonra fizik muayene ve ekokardiyografik değerlendirme yapıldı, prenatal ve postnatal tanılar karşılaştırıldı.

Bulgular: Fetal ekokardiyografi yapılan 1536 olgunun 144'ünde konjenital kalp hastalığı saptandı ve bu olguların 20'sine kardiyak malpozisyon tanısı konuldu. Kardiyak malpozisyonlu olguların 16'sında konjenital kalp hastalığı ve 4'ünde kalp dışı nedenlere bağlı malpozisyon mevcuttu. Altı olguda izole dekstrokardi, 3 olguda *situs inversus totalis*, 6 olguda *situs ambigus* ve 1 olguda izole levokardi ile birlikte *situs inversus* saptandı.

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Kalp dışı nedenlere bağlı malpozisyonlu 4 olgunun 2'sinde mezopozisyon, 1'inde dekstropozisyon ve 1'inde ileri levopozisyon mevcuttu. Altı olguya yapılan otopsi bulguları prenatal ekokardiyografik bulgular ile benzerdi. Konjenital kalp hastalığına bağlı kardiyak malpozisyonlu diğer olguların doğum sonrası ekokardiyografik sonuçları prenatal tanılarıyla karşılaştırıldığında aynı sonuçlar elde edildi.
Sonuç: Kardiyak malpozisyonun doğru tanısı için fetüsün sağ/sol aksı doğru saptanmalıdır. Bu nedenle fetal *situs* ve fetüsün sağ/sol aksının saptanmasında kolay ve güvenilir bir teknik olan Cordes tekniğini öneriyoruz. *(Anadolu Kardiyol Derg 2011; 2: 131-6)*
Anahtar kelimeler: Fetal ekokardiyografi, fetal *situs*, fetal kardiyak malpozisyon, dekstrokardi, *situs ambigus*, Cordes tekniği

Introduction

Fetal cardiac malpositions are difficult to diagnose in routine screening ultrasound. Determining the fetal right/left axis is essential for the diagnosis. Constantly variable fetal position within the uterus can confuse distinguishing the right/left side of the fetus. Variability among echocardiographers regarding image acquisition adds to this confusion. If there is confusion regarding the right/left axis, then atrial and visceral *situs*, cardiac position and cardiac segmental anatomy cannot be evaluated correctly. There are some recommended techniques and images required for a standard fetal echocardiogram (1-6).

In this study, the 20 cases among 1536 cases diagnosed as cardiac malposition using standardized technique recommended by Cordes et al. (2) for assignment of fetal right / left axis were evaluated. The accuracy of prenatal diagnosis was compared with postnatal echocardiographic diagnosis and autopsy findings.

Methods

Study patients

We studied retrospectively 1536 cases whose fetal echocardiographic examinations were performed between 1999 and 2006 in prenatal cardiology unit. Among these, cardiac malposition was determined in 20 cases and these cases performed our study group. These cases were referred to our center either from the departments of obstetrics and gynecology of our institution or from other centers by obstetricians or by pediatric cardiologist. Some were siblings of our patients with congenital heart defects and fetuses of mothers with congenital heart defects. Data of 20 cases with cardiac malposition were evaluated in respect to gestational week, maternal age, maternal and familial medical histories, previous obstetric history, fetal and postnatal echocardiographic examinations, and autopsy findings.

Fetal echocardiography

The prenatal and postnatal echocardiographic examinations were performed using a Trinitron GE Vivid Five performance echocardiographic scanner with 2.5-5 MHz transducers (Cardiovascular Ultrasound Systems, General Electric, Horten, Norway). All echocardiographic examinations were performed by the same pediatric cardiologist and all studies were recorded on videotape. The fetal examination included the standard positions used in fetal heart scanning technique (7). The cardiac axis and position were determined according to the technique described by Cordes et al. (2).

Cordes technique

In this technique the fetal head and sagittal plane of fetal body are then located. The transducer is oriented so that it is parallel to the fetal sagittal plane, with the fetal head on the right side of the video screen. When the transducer is aligned parallel to the fetal cranial-caudal axis this way, the side of the transducer toward the fetal head can be designated the "top" of the transducer. The transducer is then rotated clockwise (from the perspective of the echocardiographer) 90 degrees, to visualize optimally a transverse image of the fetal thorax. In this transverse image, the fetus' left side is on the right of the video screen, and the fetus' right side is on the left of the video screen (Fig. 1) (2).

A systematic approach was used based on segmental anatomy (8, 9). Viscero-atrial *situs* was determined as *situs solitus*, *inversus*, or *ambiguous*. In this study, the type of cardiac malposition was determined by the cardiac base-apex axis as dextrocardia, mesocardia and levocardia.
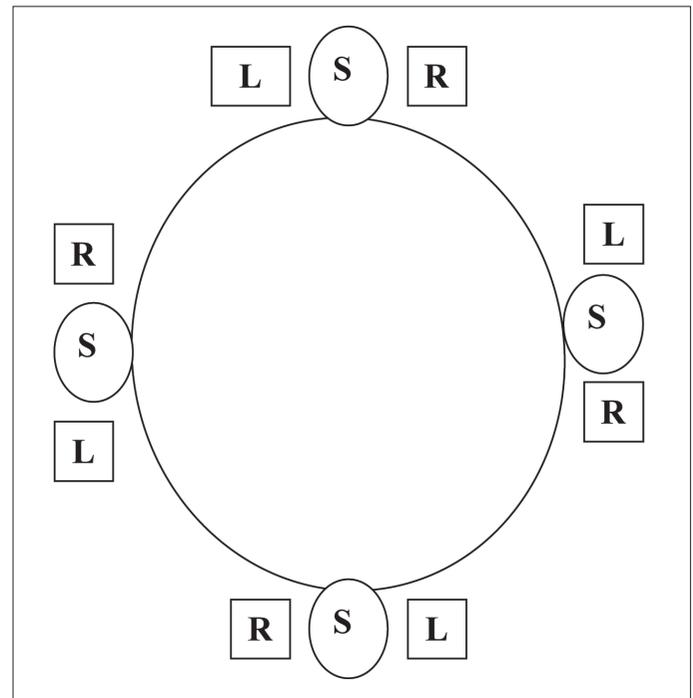

Figure 1. Schematic drawing of fetal trunk as viewed in transverse plane on video display

With fetal spine used as landmark, right and left sides of fetus can be determined. Relationship of right and left sides of fetus and spine are constant despite fetal rotation from face up (bottom), right side up (left), face down (top), and left side up (right)

S - spine, L - left, R - right (modified from Cordes TM, O'Leary PW, Seward BS, Hagler DJ. Distinguishing right from left: A standardized technique for fetal echocardiography. J Am Soc Echocardiogr 1994; 7:47-53)

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Situs solitus was defined as liver on the right side and the stomach on the left side, with the right inferior caval vein and the superior caval vein connecting to the systemic right atrium on the right side. *Situs inversus* was defined as a mirror-image configuration so that the liver was on the left side and the stomach was on the right, with the left inferior caval vein and superior connecting to the systemic right atrium on the left. *Situs ambiguous* was defined as the liver on the midline position and indeterminate stomach *situs*, abnormal inferior caval vein connection, or relations with the descending aorta. *Situs ambiguous* was divided into two major subtypes: left atrial isomerism and right atrial isomerism. These were categorized based on the following echocardiographic criteria: a diagnosis of left atrial isomerism was made if there was an interrupted inferior caval vein with azygous continuation and anterior located descending aorta according to azygous vein, and a diagnosis of right atrial isomerism was made if the inferior caval vein and aorta was both located on the right or left side of the spine in parallel anteroposterior orientation (8, 9).

In this study, dextrocardia was defined as the location of the heart in the right hemithorax with the apex pointing to the right. Dextrocardia was divided into two subgroups: Isolated dextrocardia and *situs inversus*. Dextrocardia was defined as isolated dextrocardia, occurring in conjunction with *situs solitus* and *situs ambiguous*. Mesocardia was defined as location of the heart with the cardiac base-apex axis directed to the midline of the thorax or with ventricular apices equally directed to both right and left sides. Levocardia was defined as the location of the heart in the left hemithorax with the apex pointing to the left. Levocardia as a cardiac malposition was also defined as isolated levocardia, occurring in conjunction with *situs inversus* and *situs ambiguous* (8). In this study, the pathologic displacement of the heart into the right or left thorax by extracardiac malformations was defined as dextroposition, mesoposition and levoposition (8).

All cases were followed-up by serial fetal echocardiograms until birth or intrauterine death occurred. In cases of intrauterine death, an autopsy was performed. After birth, physical and echocardiographic examinations were done and prenatal and postnatal diagnoses were compared.

Statistical analysis

All statistical analyses were performed using the SPSS 15.0 statistical software (Chicago, IL, USA). Quantitative variables are expressed as mean ± standard deviation, and qualitative variables are given as frequency and percentage. Reliability of fetal echocardiography for diagnose of cardiac malpositions was evaluated by sensitivity and specificity formulas.

Results

Of 1536 fetal echocardiograms performed, 144 revealed congenital heart diseases (9.4%), among these cases, 20 were diagnosed with cardiac malposition. Of these cases, 16 had congenital heart disease, and 4 had extracardiac malformation (Table 1). All the other cases (124 cases) had *situs solitus*, levocardia and left cardiac axis between 60° and 90°. The mean gestational age and the maternal age at the time of first examination was 28±5 weeks (range 20-37 weeks) and 30.0±3.6 years (range 24-35 years), respectively.

The indications for referral for fetal echocardiographic examination were suspected congenital heart disease, fetal arrhythmia, and fetal hydrops on routine obstetric ultrasound. Seven of 20 cases were referred for fetal echocardiography after a preliminary diagnosis of cardiac malposition. One case, referred for fetal echocardiography after a preliminary diagnosis of dextrocardia on obstetric ultrasound and magnetic resonance imaging examination, had normal cardiac anatomy and position. Except the cases 10 and 18, maternal and familial medical histories, and previous obstetric history of all cases were unremarkable. Case 10 had a sibling with *situs inversus* totalis and transposition of the great arteries, and the mother of the case 18 had congenital heart disease.

Of 20 cases with cardiac malposition, 16 cases had congenital heart disease, four cases had extracardiac malformation. There were six cases of isolated dextrocardia, three cases of *situs inversus* totalis, and six cases of *situs ambiguous*, and one case of *situs inversus* with levocardia (Fig. 2A-B) (Table 1). Of six cases with *situs ambiguous*, five cases had left atrial isomerism and levocardia (Fig. 3A-B) and one case had right atrial isomerism and dextrocardia (Fig. 4). Of four cases with cardiac malposition caused by extracardiac congenital malformation, two cases had mesoposition due to pleural effusion, one case had dextroposition due to left-sided congenital diaphragmatic hernia, and one case had an extreme levoposition due to cystic adenomatoid malformation in the right lung (Table 1). All of them had normal cardiac anatomy.

In follow-up, in six cases (case 10, 11, 13, 14, 16, and 19) pregnancy was terminated (Table 1). The autopsy findings of these cases were the same as their prenatal echocardiographic findings. The remaining cases were born and have survived the neonatal period.

On postnatal echocardiographic examination these cases had the same echocardiographic findings with prenatal diagnosis. There were not false negative and false positive results in the cases with cardiac malposition, in terms of fetal echocardiographic diagnosis. The sensitivity of the prenatal echocardiographic examination in diagnosing cardiac malpositions was calculated as 100% and specificity was 100%.

Discussion

Recently, advances in ultrasound technology and increased experience in fetal echocardiography have led to increased sensitivity and specificity of fetal echocardiography in the accuracy of diagnose of congenital heart disease (10-12). However, the prenatal diagnosis of cardiac malpositions is difficult.
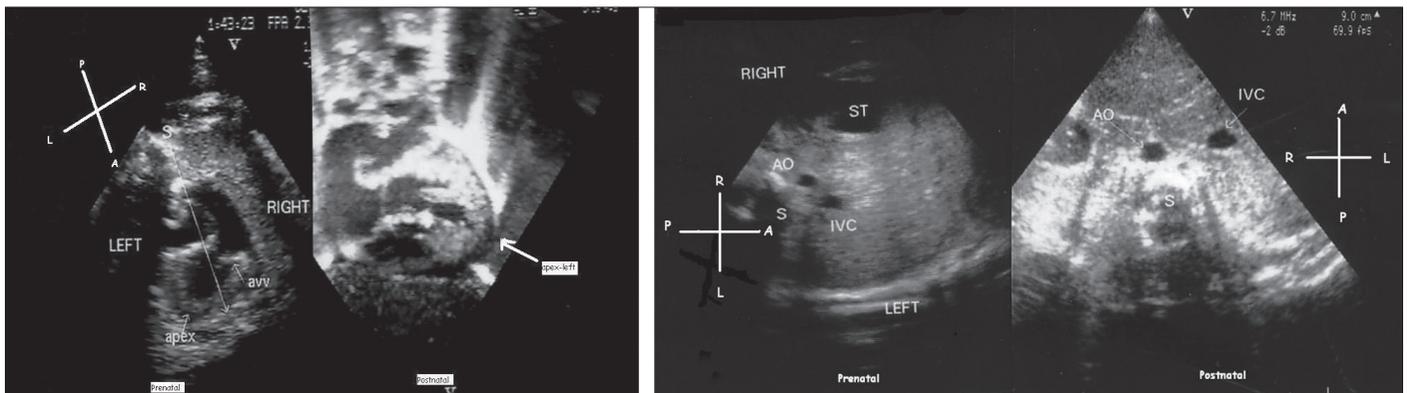
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Figure 2. Prenatal and postnatal echocardiographic images demonstrating isolated levocardia in the fetus with complex cardiac anomaly. A: With fetal spine used as landmark, the apex of the heart is directed toward the left side of the fetal chest (schematic drawing left side up) B: The fetal stomach and the aorta are positioned in the right side (schematic drawing left side down)
AVV - atrioventricular valve, S - spine, Ao - Aorta, IVC - inferior vena cava, ST - stomach, A - anterior, P - posterior, L - left, R - right
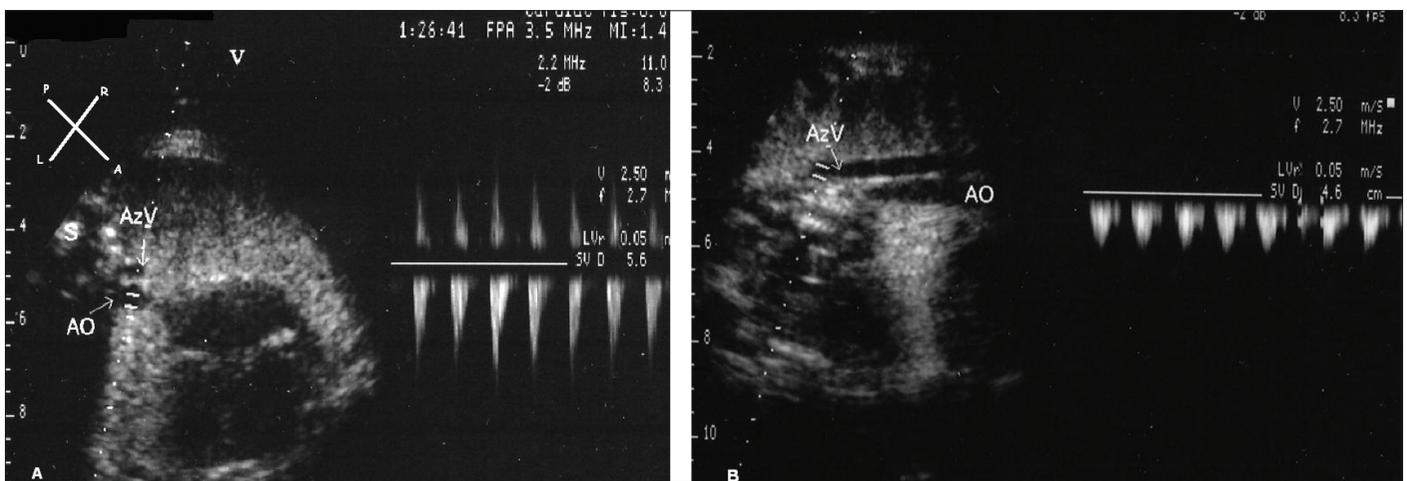

Figure 3. Four-chamber view in the fetus with left atrial isomerism. A: Two vessels are seen in front of the spine, the larger, more anterior vessel is the descending aorta, the smaller one the azygous continuation of the inferior vena cava (schematic drawing left side down) B: Two vessels are seen in the posterior thorax, the more posterior proved to be the azygous continuation of the inferior vena cava
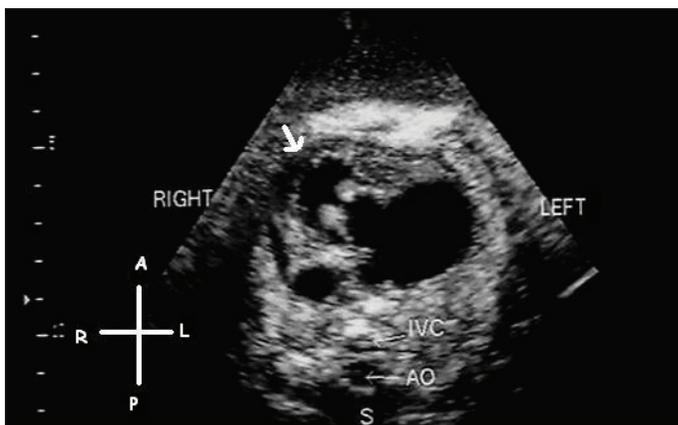S - spine, Ao - aorta, AzV - azygous vein, A - anterior, P - posterior, L - left, R - right

Figure 4. Dextrocardia and right atrial isomerism in the fetus with common inlet right ventricle. With fetal spine used as landmark, the apex (arrow) of the heart is directed toward the right side of the fetal chest and the abdominal vessels showing the aorta and inferior vena cava lying antero-posteriorly to each other and directly in front of the spine (schematic drawing left side down and right side down)
S - spine, Ao - aorta, IVC - inferior vena cava, A - anterior, P - posterior, L - left, R - right

Therefore, cardiac malpositions are usually diagnosed by postnatal echocardiographic examination or autopsy. The current methods to distinguish the right side of the fetus from the left side on the transabdominal ultrasound examination rely on several parameters including maternal position, fetal position and transducer orientation. In present study, visceroatrial *situs*, cardiac position and cardiac segmental anatomy were evaluated according to the technique described by Cordes et al. (2). Since 1998, in our prenatal cardiology unit this technique has been preferred because it is easily applied, and it reduces confusion significantly relating to fetal right/left axis. This study using Cordes technique showed that there was no difference between the type of cardiac malposition diagnosed prenatally and postnatally (sensitivity and specificity 100%).

There are a few published studies about malpositions (13-16). Walmsley et al. (16) retrospectively reviewed the fetal echocardiographic diagnosis of dextrocardia in large series. In this study, 85 cases of dextrocardia were diagnosed from 5539 fetal echocardiograms and thirty-three of these cases had been referred for fetal

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Table 1. Diagnoses and features of the cases with cardiac malposition

Cases	Gestational age at presentation, weeks	Visceroatrial situs	Cardiac apex orientation	Cardiac Axis	Congenital heart disease	Extracardiac anomalies	Outcome
Case 1	27	Ambiguous (left atrial isomerism)	Isolated Levocardia	Left axis 77°	AVSD DORV PS hemiazygous vein continuation	-	Alive, Following-up
Case 2	30	Ambiguous (left atrial isomerism)	Isolated Levocardia	Left axis 75°	AVSD azygous vein continuation	- -	Alive, Following-up
Case 3	32	Ambiguous (left atrial isomerism)	Isolated Levocardia	Left axis 65°	Sup.Inf. Ventricle VSD+ASD Ventriculo-arterial discordance azygous vein continuation		Alive, Following-up
Case 4	28	Ambiguous (left atrial isomerism)	Isolated Levocardia	Left axis 70°	DORV Subpulmonic VSD PS hemiazygous vein continuation	-	Alive, Following-up
Case 5	30	Inversus	Isolated Levocardia	Left axis 80°	DIRV Pulmonary atresia ASD MAPCA	-	Alive, Following-up
Case 6	37	Ambiguous (right atrial isomerism)	Dextrocardia	Right axis 75°	Common inlet right ventricle Large primum and secundum ASD (common atrium), MGA+Hypoplastic pulmonary artery	-	Intrauterine fetal death and autopsy was performed
Case 7	34	Solitus	Isolated Dextrocardia	Right axis 60°	DORV VSD	-	Alive, Following-up
Case 8	23	Solitus	Isolated Dextrocardia	Right axis 60°	Primum ASD Common inlet single ventricle MGA	-	Alive, Following-up
Case 9	21	Ambiguous (left atrial isomerism)	Isolated Levocardia	Left axis 72°	VSD Sinus venosus ASD azygous vein continuation	-	Alive, Following-up
Case 10	24	Inversus	Dextrocardia	Right axis 68°	TGA VSD	-	Pregnancy termination and autopsy
Case 11	24	Solitus	Isolated Dextrocardia	Right axis 60°	Common inlet single ventricle Common atrium	-	Pregnancy termination and autopsy
Case 12	34	Inversus	Dextrocardia	Right axis 70°	VSD	-	Alive, Following-up
Case 13	19	Solitus	Isolated Dextrocardia	Right axis 60°	Primum ASD Dimunitive RV+Inlet VSD (small)+INCVM+PA	-	Pregnancy termination and autopsy
Case 14	18	Solitus	Isolated Dextrocardia	Right axis 60°	Outlet VSD	Gastroschisis	Pregnancy termination and autopsy
Case 15	37	Inversus	Dextrocardia	Right axis 58°	Primum ASD Common ventricle	-	Alive, Following-up
Case 16	24	Solitus	Isolated Dextrocardia	Right axis 30°	Primum ASD Common ventricle	-	Pregnancy termination and autopsy
Case 17	22	Solitus	Mesoposition	0°	-	Pleural effusion	Alive, Following-up
Case 18	33	Solitus	Dextroposition	Left axis 45°	-	Diaphragmatic hernia	Repair of diaphragmatic hernia and alive
Case 19	24	Solitus	Extreme Levoposition	Left axis 30°	-	Cystic adenomatoid malformation	Pregnancy termination and autopsy
Case 20	20	Solitus	Mesoposition	0°	-	Pleural effusion	Alive Following-up

ASD - atrial septal defect, AVSD - atrioventricular septal defect, DIRV - double inlet right ventricle, DORV - double-outlet right ventricle, INCVM - Isolated non-compaction of the ventricular myocardium, MAPCA - multiple aortopulmonary collateral arteries, MGA - malposition of the great arteries, PA - pulmonary atresia, PS - pulmonary stenosis, RV - right ventricle, Sup. Inf- Superioinferior, TGA - Transposition of the great arteries, VSD - ventricular septal defect

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echocardiography after a preliminary diagnosis of dextrocardia on routine ultrasound examination. In present study, only seven of 20 cases were referred for fetal echocardiography after diagnosis of cardiac malposition on routine obstetric ultrasound, and the cases whose preliminary diagnosis of dextrocardia on obstetric ultrasound and magnetic resonance imaging had normal cardiac anatomy and position on pre-postnatal echocardiogram. These studies have shown that fetal cardiac malpositions are difficult to diagnose on routine obstetric ultrasound.

Fetal cardiac malposition is caused by either intrinsic congenital heart diseases or extracardiac malformations. Generally, intrinsic congenital heart diseases cause abnormal cardiac axis (17, 18). In addition, extracardiac malformations are often responsible for the abnormal location of the heart in the thorax due to mediastinal shift (19). In our study among 20 cases with cardiac malposition, 16 had congenital heart disease, and four had extracardiac malformation.

Most of the cases with congenital heart disease had abnormal cardiac axis. Shipp et al. (20) reported that 44% of fetal heart defects were associated with left-sided heart greater than 57 degrees. Smith et al. (17) also reported that left-sided heart greater than 75 degrees correlated with a positive predictive value of 76% for a heart defect in fetuses. In most of our cases with levocardia and dextrocardia, cardiac axis was greater than 57 degrees (Table 1).

Of six cases with *situs ambiguous*, five had left atrial isomerism and one right atrial isomerism. This study demonstrated significant predominance of fetuses diagnosed with left atrial isomerism. Some studies have noted that fetuses with left atrial isomerism appear to be more common *in utero* because of an increased rate of very early death of fetuses with right atrial isomerism (15). All cases with *situs ambiguous* had severe complex congenital heart disease. It was stated that the cardiac anomalies in right atrial isomerism tend to be more severe than those in left atrial isomerism (18). This study also indicated that the prognosis of cases with left atrial isomerism was better than case with right atrial isomerism.

Of four cases with cardiac malposition due to extracardiac anomalies, one had congenital diaphragmatic hernia and other had cystic adenomatoid malformation. Although previous studies were reported that these anomalies could be associated with cardiac defects and other anomalies, our cases had normal cardiac anatomy (18, 21, 22).

Conclusion

The fetal right/left side and axis must be determined correctly for the accurate diagnosis of cardiac malpositions. Therefore, we recommend that Cordes technique provides a simple and reliable determination of the fetal right/left side and fetal *situs*.

Conflict of interest: None declared.

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