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Original Research

Altered Intervessel Distances in Right and Double Aortic Arch Anomalies on the Fetal Echocardiography Three-Vessel View

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Abstract

Background: The main aim of this study is to increase the recognizability of aortic arch anomalies during fetal echocardiographic examination. To evaluate intervessel distances in the three-vessel view in fetuses with isolated right or double aortic arch (DAA) anomalies during fetal echocardiography. **Methods**: This retrospective study included six fetuses examined between 19^{+0} and 21^{+0} weeks of gestation, with isolated right or DAA anomalies confirmed postnatally. Five fetuses had an isolated right aortic arch (RAA) anomaly, while one had an isolated DAA anomaly. Diameters of the main pulmonary artery (PA) and ascending aorta (Ao) were measured from the three-vessel view. Additionally, intervessel distances between the main PA–Ao, the Ao and superior vena cava (Ao–SVC), and the main PA–SVC were assessed. The standard deviation (SD) values were assessed using nomograms appropriate for gestational age. **Results**: The diameters of the PA and Ao were not significantly different from those in the normal population in any of the fetuses. In five of the six fetuses, the PA–Ao distance exceeded +3 SD, indicating an increase compared with fetuses without congenital heart defects. Additionally, the PA–SVC distance exceeded +3 SD in four fetuses, indicating a marked increase compared to fetuses without congenital heart anomalies. In contrast, the Ao–SVC distance was below –3 SD in only two fetuses, indicating a decrease, while no significant deviation was observed in the remaining four cases. **Conclusions**: In fetal echocardiography, isolated right or DAA anomalies can lead to altered intervessel distances on the three-vessel view. Notably, increases in the PA–Ao and PA–SVC distances were observed.

Keywords: aortic arch anomaly; congenital heart disease; fetal echocardiography; three-vessel view

1. Introduction

Congenital heart anomalies are among the most common congenital structural anomalies. When viewed on a population basis, the prevalence varies, with reported birth prevalence ranging from 6.9 to 19.1 per 1000 births [1,2]. Although the implementation of routine screening programs has improved prenatal diagnosis rates, the prenatal diagnosis rate for congenital heart disease remains around 60% [3]. However, it has been emphasized that this rate varies among countries and that significantly lower prenatal diagnosis rates may exist [4]. Additionally, the diagnosis rate is higher in certain specific anomalies such as hypoplastic left heart syndrome [5]. However, the prenatal detection rates of anomalies such as transposition of the great arteries are significantly lower [6].

Aortic arch anomalies, however, are relatively rare. Although isolated cases are generally asymptomatic, associations with 22q11 deletions have been documented [7]. Although the association between isolated aortic arch anomalies and genetic disorders is uncommon, it has been documented previously. Therefore, if such an anomaly is identified, amniocentesis is recommended for genetic evaluation [8]. Recognition of aortic arch anomalies may be beneficial in improving the detection of prenatal genetic disorders.

Additionally, approximately 21% of cases may experience respiratory distress in the early postnatal period [9]. Considering these factors, prenatal diagnosis is crucial. Postnatal tracheal obstruction and related symptoms can occur in association with right aortic arch (RAA) anomalies [10]. Therefore, establishing an early prenatal diagnosis is important for improving postnatal prognosis [11].

Recommendations for isolated RAA diagnosis include the evaluation of the descending aorta and three-vessel tracheal (3VT) view [12]. These recommendations involve examining the distal segments relative to the heart. This study demonstrated that even in the more proximal lower segments, changes may be present in right or double aortic arch DAA anomalies.

This study aimed to identify changes in intervessel distance in the three-vessel view, which is routinely used during second-trimester fetal echocardiography screening, in the presence of right or DAA anomalies. Therefore, we aimed to improve the prenatal detection rate of right or DAA anomalies.

2. Materials and Methods

This study was conducted at Faculty of Medicine, Suleyman Demirel University. Data were obtained from the archived records stored in the ViewPoint imaging and re-

porting system (ViewPoint 6, GE Healthcare, Chicago, IL, USA). The clinical records of the patients who underwent examination between January 2019 and June 2021 were retrieved.

2.1 Study Design

Fetuses diagnosed with right or DAA anomalies via fetal echocardiography between 18–24 weeks of gestation in the perinatology clinic, and whose diagnoses were confirmed by pediatric cardiology at postnatal follow-up, were included in the study. An isolated right or DAA anomaly was defined as an anomaly that did not include ductal arch anomalies, an aberrant left subclavian artery, an interrupted aorta, or aortic coarctation, as determined by postnatal pediatric cardiology evaluation.

The inclusion criteria were as follows: singleton pregnancy, obtaining and recording a three-vessel view in the ViewPoint system, maternal subcutaneous fat thickness <6 cm, and the absence of other fetal cardiac or non-cardiac anomalies. Participants were excluded if the diagnosis was not confirmed by pediatric cardiology during the postnatal period or if there were any extracardiac anomalies.

The ultrasound examination data of pregnant women between 18–23 weeks of gestation who visited the perinatology clinic at a tertiary center were retrieved using the ViewPoint system. Imaging was performed using a Voluson E6 Ultrasound System (GE Healthcare, Little Chalfont, UK) with a 1–5 MHz convex probe.

All measurements were performed by a perinatology specialist, Dr. ÜKT, and documented accordingly. These images are presented in this study.

2.2 Evaluated Variables

Six fetuses that met the criteria were included in the study. Fetal biometric measurements were evaluated, and gestational age was calculated based on the last menstrual period (if a discrepancy of more than one week was found between the fetal biometric measurements, the first-trimester measurements were used for correction). Maternal abdominal subcutaneous fat thickness was also assessed.

In this study, assessments were performed using the three-vessel view obtained during routine fetal echocardiographic examination. The image was zoomed to fill approximately two-thirds of the screen. The Doppler mode was not used. Images of the pulmonary artery (PA), aorta (Ao), and superior vena cava (SVC) were acquired. Distances between vessels were evaluated as the shortest distance between two vessels, and measurements were taken from lumen to lumen. Measurements were taken electronically from images. A sample image with color enhancement was provided in Fig. 1A.

The distances between the main PA–Ao, between the Ao–SVC, and between the main PA and the SVC were measured within the vascular lumen (PA–SVC) in the 3-vessel view (Fig. 1A) [13].

The standard deviations (SD) of the measurements were calculated based on nomogram values determined in previous studies [13,14]. All measurements were expressed as SD from the mean and were evaluated using nomograms adjusted for fetal gestational age. The great vessel diameters were calculated using the following website: https://www.perinatology.com. The z-scores and SD ranges were calculated and are presented in Table 1 (Ref. [13]). For the measurements of the distances between the great vessels, our previously published study, *'Evaluation of Three-Vessel View Intervessel Distance Measurements in Fetuses Without Congenital Cardiac Defects'*, was used as a reference [13]. Reference values from this publication were used to calculate SDs based on within-group variation.

A post hoc power analysis was conducted based on the PA–Ao data, with control group parameters derived from a previous study. The control group included 96 participants (mean: 1.4, SD: 0.2), while the experimental group had six participants (mean: 2.53, SD: 0.39). The pooled SD was 0.21, indicating a large effect size (Cohen's d = 5.29). Statistical power was estimated to be approximately 100% using a two-tailed test with a significance level of 0.05. These results demonstrate that despite the small size of the experimental group, the sample sizes were sufficient to detect the observed differences with high confidence.

In addition to the post hoc analysis, an a priori power analysis was conducted using G*Power 3.1.9.7 (Heine University, Düsseldorf, Germany; http://www.gpower.hhu.de) for a two-tailed independent-samples t-test ($\alpha = 0.05$, power = 0.80). Assuming a large effect size (Cohen's d = 0.8, conventionally considered "large"), a total sample size of 52 participants (26 per group) would be required to achieve sufficient statistical power. The post hoc power analysis indicated sufficient statistical power owing to the large observed effect size; however, this did not replace the need for an a priori power calculation. Although an a priori analysis indicated that 52 cases were required, only six cases were included in this study. This increases the risk of statistical errors and limits the generalizability of our findings. Therefore, these results should be considered preliminary, interpreted with caution, and confirmed in larger cohorts.

2.3 Statistical Analysis

Data were expressed as mean $\pm$ SD for continuous data or frequencies (n) with percentages (%) for categorical data.

3. Results

The gestational ages of the six fetuses included in the study ranged from 19^{+1} to 20^{+5} weeks. In five of the six fetuses, a RAA anomaly was present (Fig. 1B–D,F,G), whereas one fetus had a DAA anomaly (Fig. 1E). The measurements of the PA diameters ranged from –1 SD to +2 SD, while the Ao diameters ranged from –1 SD to +3 SD. The

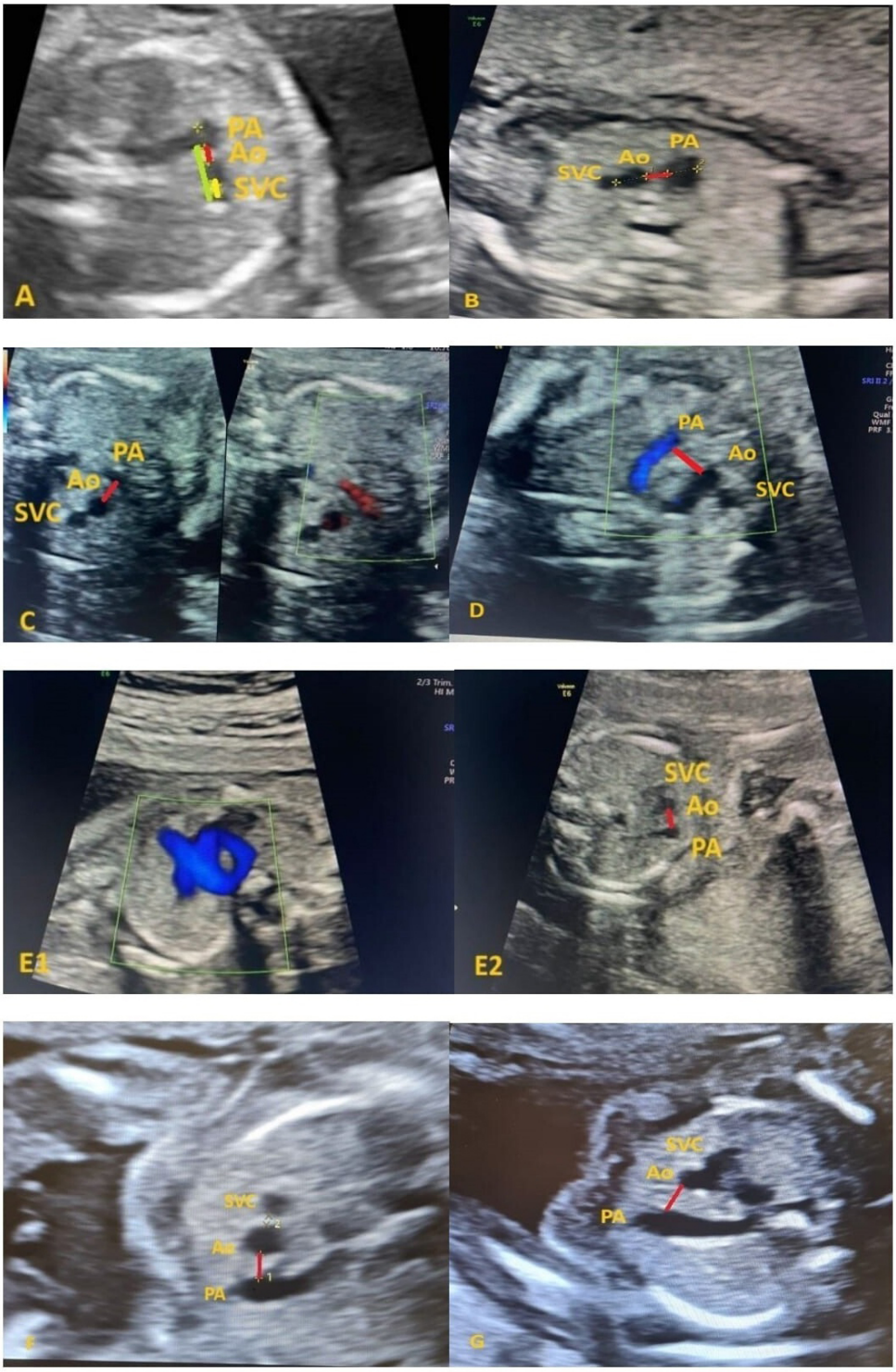

Fig. 1. Representation of 3-vessel views in the fetal echocardiographic examination of all cases included in the study. (A) Demonstration of the distance measurements between vessels in the three-vessel view during fetal echocardiography in a fetus without anomalies [13]. (B) Case 1, a 20^{+1} weeks fetus with a RAA anomaly. (C) Case 2, 20^{+2} weeks fetus with a RAA anomaly. (D) Case 3, 19^{+2} weeks fetus with a RAA anomaly. (E1) Case 4, 20^{+2} weeks fetus with a DAA anomaly shown with color Doppler. (E2) Case 4, 20^{+2} weeks fetus with a DAA anomaly shown in the three-vessel view. (F) Case 5, 20^{+5} weeks fetus with a RAA anomaly. (G) Case 6, 19^{+1} weeks fetus with a RAA anomaly. PA, pulmonary artery diameter; Ao, aortic diameter; SVC, vena cava superior diameter; RAA, right aortic arch; DAA, double aortic arch. Red line, distance between PA and Ao; yellow line, distance between Ao and SVC; green line, distance between PA and SVC.

PA–Ao distance was found to be above +3 SD in five out of the six cases, while in only one fetus, it was evaluated between +1 SD and +2 SD. The PA–SVC distance was above +3 SD in four of the six fetuses. The remaining two fetuses were evaluated between 0 to +1 SD and +2 SD to +3 SD. In the Ao–SVC distance, only 2 fetuses had values below –3 SD, while no significant changes were observed in the other fetuses (Table 1).

Fig. 1A shows a demonstrative representation of the measurements for a fetus without any cardiac anomalies, whereas the subsequent measurements are presented as images specific to each case.

4. Discussion

This study suggests that isolated right and DAA anomalies may be associated with certain changes in inter-vessel distances observed during fetal echocardiography in the three-vessel view. In particular, increases in the PA–Ao and PA–SVC distances were noted. Distortions in the appearance of the main PA, Ao, and SVC in the three-vessel view may provide clues that warrant a more detailed evaluation of the superior sections.

Traditionally, RAA anomalies are diagnosed by a U-shape instead of a V-shape in the 3VT section [15]. The aortic arch was also observed passing to the right of the trachea and connecting to the descending aorta [12]. In a previous study, the expression "a gap between the Ao and main PA in the three-vessel view" was used to refer to changes in the distance between the vessels in more proximal sections. However, no objective numerical values have been provided [12]. The strongest aspect of this study is that we objectively demonstrated the PA–Ao distance by calculating the SD of the nomograms. Additionally, we determined that not only the PA–Ao distance, but also the PA–SVC distance increased.

In this study, we also observed an increase in the distance between the main PA–SVC in the three-vessel view, which has not been previously studied in right/DAA anomalies. In these four cases, the increase was significant, exceeding +3 SD; however, in two cases, this increase was not noticeable.

The Ao–SVC distance was found to be below –3 SD in two out of six fetuses, and the distance between the two vessels was reduced. However, the fact that this measurement has not been demonstrated in other fetuses reduces its applicability.

In a single fetus diagnosed with a DAA, we found increases exceeding 3 SD in both PA–Ao and PA–SVC distances. Based on this case, we demonstrated that these two measurements may vary not only in isolated RAA anomalies but also in isolated DAA anomalies. However, further studies with larger numbers of cases are required.

In Case 1, which involved an isolated RAA anomaly, only moderate increases were observed in both PA–Ao and PA–SVC measurements. Based on this case, although an increase of more than +3 SD in the PA–Ao distance was detected in four of the five (80%) isolated RAA cases, it should be noted that moderate increases may also occur. This suggests that individual variations may exist at the case level. In other words, the presence of an RAA anomaly may be possible even without a marked increase in the distance between the great vessels.

Fetal heart evaluation is primarily performed using ultrasound. Standard screening for fetal heart assessment is also performed using ultrasound [16]. In particular, because of fetal radiation exposure, the use of computed tomography (CT) remains limited. In fetal heart examination, although fetal magnetic resonance ımaging (MRI) has not been shown to be superior to fetal echocardiography in assessing structural heart anomalies, it may increase the diagnostic rate in fetal congenital heart disease [17]. Therefore, fetal echocardiography and fetal heart examinations are widely used. This study may thus contribute valuable insights to fetal echocardiographic evaluation.

Differential diagnoses of the aortic arch are made during fetal echocardiography examinations [18]. Color Doppler flow imaging (CDFI) and high-resolution flow imaging (HDFI) techniques are used to increase the accuracy of diagnosing the right or DAA [19]. However, a previous study also used the 3VT view and higher-level sections [19]. However, this study showed that changes may also occur in right or DAA anomalies in more proximal sections. In right or DAA anomalies, changes in the distance between the major vessels were detected in the three-vessel section. These changes may raise suspicion among clinicians and lead to a more detailed examination of the higher segments.

Numerous studies have focused on the differential diagnosis between the RAA and DAA [18,20,21]. DAA tends to be symptomatic earlier and more frequently than RAA, and accurate prenatal diagnosis can improve postnatal prognosis [11,22]. However, in this study, we observed an increase in PA–Ao and PA–SVC distances in both anomalies in the proximal cuts. Although the possibility of using these anomalies in early differential diagnoses has not yet been determined, this issue can be clarified by studies involving a much larger number of cases.

Although isolated aortic arch anomalies may be compatible with postnatal life, early prenatal diagnosis enables timely counseling and multidisciplinary planning. In some cases, particularly those associated with other major anomalies or genetic syndromes, pregnancy termination may be considered an option. Therefore, each case should be evaluated individually, and families should be provided with comprehensive counseling regarding prognosis, potential interventions, and postnatal outcomes.

Limitations

This study has some limitations. The most significant limitation was the inclusion of patients with an isolated right or DAA, and since the patients were selected only after postnatal confirmation, the study included only six cases.

Table 1. The evaluation of the main vessel diameters and the intervessel distance measurements in the three-vessel view during fetal echocardiography.

	1. Case	2. Case	3. Case	4. Case	5. Case	6. Case
Type of Aortic Arch Anomaly	Right arcus aorta	Right arcus aorta	Right arcus aorta	Double arcus aorta	Right arcus aorta	Right arcus aorta
Gestational Age (weeks)	20^{+1}	20^{+2}	19^{+2}	20^{+2}	20^{+5}	19^{+1}
Biparietal diameter (BPD) (mm)	45	45	46	47	47	43
Ao (mm)*	2.7 (–1 SD)	2.8 (0 to –1 SD)	3.5 (+1 SD to +2 SD)	3.9 (+1 SD to +2 SD)	3.7 (0 to +1 SD)	2.8 (–1 SD to 0)
Pa (mm)*	4.4 (+2 SD to +3 SD)	2.7 (–1 SD to –2 SD)	3.8 (+1 SD to +2 SD)	3.9 (+1 SD to +2 SD)	4.3 (+1 SD to +2 SD)	3.2 (0 to +1 SD)
Pa-Ao (mm)[a]	1.8 (+1 SD to +2 SD)	2.5 (>+3 SD)	2.5 (>+3 SD)	2.8 (>+3 SD)	2.7 (>+3 SD)	2.9 (>+3 SD)
Ao-SVC (mm)[a]	1.1 (–1 SD to 0)	1 (–1 SD)	0.8 (<–3 SD)	1.2 (0)	1.1 (–1 SD to 0)	0.8 (<–3 SD)
Pa-SVC (mm)[a]	6.0 (0 to +1 SD)	7 (>+3 SD)	6.4 (+2 SD to +3 SD)	7.3 (>+3 SD)	7.6 (>+3 SD)	6.7 (>+3 SD)

SD, standard deviation.

* https://www.perinatology.com/calculators/Fetal%20Echocardiogram%20Z%20Score%20Calculator.html.

[a] Turgut ÜK, Erdemoğlu E, Sezik M. Evaluation of three-vessel view intervessel distance measurements in fetuses without congenital cardiac defects. Journal of Clinical Ultrasound: JCU [13].

However, the lack of similar studies in the literature on right or DAA anomalies, and the presentation of data with objective values, may serve as a step forward for future research in this field. Second, the postnatal evaluation was based solely on pediatric cardiology echo examinations. Aortic arch variations and anomalies can be detected asymptomatically in the pediatric age group but may also cause a wide range of symptoms, from respiratory distress to more severe manifestations. Multidetector CT is widely used for the clinical diagnosis of aortic arch variations/anomalies [23]. It has been shown that, in the postnatal evaluation of fetuses prenatally diagnosed with an isolated RAA, inconsistencies may occasionally occur during postnatal diagnostic confirmation. Additionally, the same study noted that CT may be superior to ultrasound for making a diagnosis [24]. In this study, isolated right and DAA anomalies were confirmed using echocardiography only during the newborn period. Because the participants were asymptomatic, CT scans were not performed.

The post hoc analysis indicated that the number of cases was sufficient. This finding was attributed to the marked increase in the intervascular distances. However, despite the post hoc analysis suggesting that six cases were adequate, the presence of a DAA anomaly in only one case and the fact that not all cases exhibited changes exceeding the three SD limit the generalizability of the results. Individual differences were observed among the six cases presented in the study. On fetal echocardiography, the distance between the great vessels in the three-vessel view may not be clearly defined in every case. Therefore, increasing the sample size may help better understand these variations and provide more definitive findings. Further studies with larger numbers of cases are needed to support these findings.

Although we proposed our hypothesis in cases of a right or DAA, its applicability may be limited to anomalies in which both the right ductal arch and RAA are present. Therefore, reevaluation and further investigation of anomalies accompanied by a right ductal arch may be necessary [25].

5. Conclusions

Isolated right and DAA anomalies may present findings on prenatal fetal echocardiography that could suggest their presence, even in more proximal cross-sections. In the three-vessel view, increases may be observed in both the PA–Ao and PA–SVC distances. However, it is important to note that these measurements can vary at the individual case level.

Availability of Data and Materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Author Contributions

ÜKT, EE, and MS designed the research study. ÜKT, EE, TŞ, and MS performed the research and collected the data. ÜKT and EE provided an ultrasonographic evaluation. ÜKT, EE, TŞ, and MS contributed substantially to the conception and design of the study, supervised surgical management, and participated in the interpretation of clinical data. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was performed in accordance with the ethical standards for human research established by the Declaration of Helsinki and Good Clinical Practice guidelines and was approved by the local Ethics Committee of Suleyman Demirel University School of Medicine (approval number: 32297). All patients provided written informed consent for the procedure and for the submission and publication of their clinical data and images.

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Conflict of Interest

The authors declare no conflict of interest.

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