Original Article

Cardiac Axis Deviation in Anomaly Scan: A Marker for Underlying Cardiac Anomalies

Yashodhan Sanjay Dhonukshe, Siddaroodha Sajjan, Suresh Kanamadi

Department of Radio-Diagnosis, Shri B.M. Patil Medical College, Hospital and Research Centre and BLDE (Deemed to be University), Vijayapura, Karnataka, India

Abstract

Background: Congenital heart defects (CHD) is a leading cause of perinatal morbidity and mortality. Cardiac axis assessment on the four-chamber view has been proposed as a simple adjunct marker for detecting underlying cardiac anomalies during second-trimester anomaly scans. **Aim:** The aim of the study was to evaluate the association between cardiac axis deviation and congenital cardiac defects and assess its diagnostic performance as a screening parameter. **Materials and Methods:** This prospective observational study included 810 pregnant women undergoing routine anomaly scans at 18–24-week gestation at a tertiary care center. Cardiac axis was measured on the four-chamber view and classified as normal (25°–65°), left deviation (>65°), or right deviation (<25°). Fetuses with suspected abnormalities underwent detailed fetal echocardiography and postnatal follow-up where feasible. Associations between axis category and anomalies were analyzed using the Chi-square test. Diagnostic performance indices were calculated. **Results:** Cardiac axis was normal in 746 (92.1%) fetuses, large in 46 (5.7%), and small in 18 (2.2%). Cardiac anomalies were detected in 51 (6.3%) cases. Anomalies were present in 31/46 (67.4%) with large axis and 15/18 (83.3%) with small axis, compared with 5/746 (0.7%) with normal axis ($P < 0.001$). Septal defects (atrial septal defect + ventricular septal defect VSD) were most frequent. Cardiac axis deviation showed sensitivity 90.2%, specificity 97.6%. Significant associations were also observed with selected extracardiac anomalies. Adverse pregnancy outcomes were more common when cardiac anomalies were present ($P < 0.001$). **Conclusion:** Cardiac axis deviation is a strong marker of congenital cardiac anomalies and provides a high rule-out value when normal. Routine cardiac axis assessment during anomaly scans can aid early risk stratification and targeted referral.

Keywords: Anomaly scan, cardiac axis, congenital heart disease, fetal echocardiography, prenatal screening

Résumé

Contexte: Les cardiopathies congénitales (CC) constituent une cause majeure de morbidité et de mortalité périnatales. L'évaluation de l'axe cardiaque sur la coupe des quatre cavités a été proposée comme un marqueur complémentaire simple pour détecter des anomalies cardiaques sous-jacentes lors des échographies morphologiques du deuxième trimestre. Objectif : L'objectif de cette étude était d'évaluer l'association entre la déviation de l'axe cardiaque et les cardiopathies congénitales, ainsi que d'analyser sa performance diagnostique en tant que paramètre de dépistage. **Matériel et méthodes:** Cette étude observationnelle prospective a inclus 810 femmes enceintes bénéficiant d'une échographie morphologique de routine entre la 18e et la 24e semaine de gestation, au sein d'un centre de soins de niveau tertiaire. L'axe cardiaque a été mesuré sur la coupe des quatre cavités et classé comme normal (25°–65°), en déviation gauche (>65°) ou en déviation droite (<25°). Les fœtus présentant une suspicion d'anomalie ont fait l'objet d'une échocardiographie fœtale détaillée et d'un suivi postnatal lorsque cela était réalisable. Les associations entre la catégorie de l'axe cardiaque et la présence d'anomalies ont été analysées à l'aide du test du Chi-deux. Les indices de performance diagnostique ont été calculés. **Résultats:** L'axe cardiaque était normal chez 746 fœtus (92,1 %), en déviation gauche (axe large) chez 46 fœtus (5,7 %) et en déviation droite (axe étroit) chez 18 fœtus (2,2 %). Des anomalies cardiaques ont été détectées dans 51 cas (6,3 %). Des anomalies étaient présentes chez 31 des 46 fœtus (67,4 %) présentant un axe large et chez 15 des 18 fœtus (83,3 %) présentant un axe étroit, contre 5 des 746 fœtus

Address for correspondence: Dr. Siddaroodha Sajjan, Department of Radio-Diagnosis, Shri B.M. Patil Medical College, Hospital and Research Centre and BLDE (Deemed to be University), Vijayapura, Karnataka, India.
E-mail: siddumsajjan@gmail.com

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(0,7 %) présentant un axe normal ($P < 0,001$). Les anomalies septales (communication interauriculaire + communication interventriculaire) étaient les plus fréquentes. La déviation de l'axe cardiaque a démontré une sensibilité de 90,2 % et une spécificité de 97,6 %. Des associations significatives ont également été observées avec certaines anomalies extracardiaques. Les issues de grossesse défavorables étaient plus fréquentes en présence d'anomalies cardiaques ($P < 0,001$). **Conclusion:** La déviation de l'axe cardiaque constitue un marqueur puissant d'anomalies cardiaques congénitales et offre une valeur d'exclusion élevée lorsqu'il est normal. L'évaluation systématique de l'axe cardiaque lors des échographies morphologiques peut faciliter une stratification précoce du risque ainsi qu'une orientation ciblée des patientes.

Mots-clés: Échographie morphologique, axe cardiaque, cardiopathie congénitale, échocardiographie fœtale, dépistage prénatal

Introduction

Congenital heart defects (CHDs) represent the most prevalent type of birth defects arising from abnormal fetal cardiac development during pregnancy and include structural or functional defects of the heart and major blood vessels.[1] The global incidence of CHD is increasing over time due to improved detection and diagnosis, with septal defects forming a major proportion.[2] Although the etiopathogenesis of CHDs is unknown, the majority of cases are complex and involve maternal, fetal, and familial factors.[3] Severe CHDs significantly affect the survival of newborns and their quality of life; however, most CHDs are mild and have a good outcome if diagnosed and treated early.[4] The global crude mortality rate due to CHDs declined to 2.8 per 100,000 population in 2019, which is due to significant advancements in cardiovascular medicine, anesthesiology, pediatrics, and surgical techniques, resulting in the survival of most CHD patients into adulthood.[5]

Early prenatal diagnosis of CHD has important implications for perinatal care, appropriate referral and delivery planning, and parental counseling.[6] The best time for screening for CHD is between 18 and 22 weeks of gestation.[6] However, technical difficulties in early pregnancy, such as the small size of the heart, low resolution of images, and movement of the fetus, make it challenging.[6] Advances in ultrasound technology and the development of standardized anomaly scans have greatly improved the ability to diagnose structural heart defects in the second trimester.[7,8] Some of the indirect ultrasound signs of CHD, such as increased nuchal translucency, tricuspid regurgitation, and abnormal ductus venosus flow, have been linked to an increased risk of CHD.[9]

The fetal cardiac axis, or the angle between the interventricular septum and the anteroposterior axis of the fetal thorax, has gained attention as an important screening tool for the early diagnosis of CHD using the anomaly scan.[10] Studies have already demonstrated that the fetal cardiac axis is abnormal in the majority of CHD-affected fetuses.[10] This has made the measurement of the fetal cardiac axis an important and practical adjunct in the screening for CHD using the routine anomaly scan.[10] The measurement of the cardiac axis is done on the standard four-chamber view of the heart and does not require any special equipment or take up much of the time of the routine anomaly scan.[10] Most of the studies on the measurement of the fetal cardiac axis as an early screening method for CHD have been done in the first trimester. There is little information on the routine anomaly scan. With this background, the present study aimed to evaluate cardiac axis deviation on anomaly scan as a marker of underlying congenital cardiac anomalies and to analyze its association with specific types of fetal cardiac defects.

Materials and Methods

This prospective observational study was conducted in the Department of Radiodiagnosis at a tertiary care center from March 2024 to August 2025. The study population comprised 810 pregnant women undergoing routine mid-trimester anomaly scanning between 18 and 24 weeks of gestation. Ethical clearance was obtained from the Institutional Ethics Committee, and written informed consent was obtained from all participants after explaining the study objectives and procedures.

The sample size was calculated using the single-proportion formula ($n = Z^2pq/d^2$). Based on the reported birth prevalence of congenital heart disease in India of approximately 9 per 1000 births,[11] P was taken as 0.009 and q as $1 - p$. With a 95% confidence level ($Z = 1.96$) and absolute precision of 0.007, the minimum required sample size was calculated to be approximately 700. A total of 810 participants were included to ensure adequate study power.

The sample size was calculated based on an anticipated proportion of cardiac axis deviation of 7.1% with absolute precision of 2% and confidence limits of 98%, resulting in a calculated sample size of 809 patients. Pregnant women aged ≥18 years with singleton pregnancy, gestational age between 18 and 24 weeks, and adequate visualization of fetal four-chamber cardiac view were included. Exclusion criteria comprised multiple pregnancies, failure to obtain adequate four-chamber view images, fetuses with isolated extracardiac malformations without suspected cardiac involvement, poor fetal positioning preventing adequate cardiac visualization, and maternal factors limiting ultrasound examination quality.

Ultrasound examinations were performed using high-end machines (GE VOLUSON S8 BT18 and GE VERSANA PREMIER) equipped with curvilinear transducers (2–5 MHz) and facilities for high-resolution imaging, color Doppler, and pulsed-wave Doppler. The transabdominal approach was used as the primary method, with the transvaginal approach employed when fetal visibility was suboptimal. All examinations were performed by radiologists experienced in fetal imaging following standardized scanning protocols. When required, measurements were reviewed by a second radiologist

to reduce observer variability. Complete fetal biometry and anatomical survey were performed, followed by detailed fetal echocardiographic evaluation focusing on four-chamber view assessment, outflow tract visualization, and cardiac position and axis measurement.

The fetal cardiac axis was measured in the four-chamber view by determining the angle between the interventricular septum and a line drawn perpendicular to the fetal spine at the level of the four-chamber view.[12] Cardiac axis measurements were classified as normal (25°–65°), left axis deviation (>65°), right axis deviation (<25°), or abnormal positioning (non-identifiable axis) [Figure 1].[13]

When cardiac anomalies were identified, detailed documentation included the type of cardiac defect, severity assessment, associated extracardiac anomalies, and recommendations for further evaluation. For cases with suspected cardiac anomalies, fetal echocardiography was performed, and postnatal confirmation was obtained through pediatric cardiology evaluation and postnatal echocardiography wherever feasible.

All collected data were entered into Microsoft Excel spreadsheets (Microsoft Corporation, Redmond, Washington, USA) and analyzed using SPSS version 26 (IBM Corp., Armonk, New York, USA). Descriptive analysis included mean ± standard deviation for continuous variables and frequencies with percentages for categorical variables. Categorical variables were analyzed using the Chi-square test. Correlation between cardiac axis measurements and types of cardiac anomalies was assessed, along with evaluation of diagnostic performance parameters, including sensitivity, specificity, positive predictive value, and negative predictive value. $P < 0.05$ was considered statistically significant.

Results

The study included 810 pregnant women undergoing anomaly scan between 18 and 24 weeks of gestation. The mean maternal age was 31.82 ± 8.19 years, with the largest proportion in the 31–40 year age group, and the mean gestational age at examination was 20.32 ± 0.85 weeks. Most participants were multigravida (79.4%). Parity distribution showed 29.4% nulliparous, 29.9% primiparous, and 40.7% multiparous women. Routine anomaly screening was the most common referral indication [Table 1].

Cardiac axis assessment showed that the majority of fetuses had a normal axis (25°–65°), whereas a smaller proportion demonstrated large or small axis deviation. The mean cardiac axis was 45.05° ±10.2°. Adequate four-chamber view visualization was achieved in nearly all cases. Most fetuses had normal cardiac position and heart size. Overall, cardiac anomalies were identified in 6.3% of the study population [Table 2].

Among fetuses with cardiac anomalies, septal defects (combined atrial septal defect and ventricular septal defect [VSD]) constituted the most frequent group, followed by tetralogy of Fallot, truncus arteriosus, and double outlet right ventricle, with other complex anomalies observed less commonly [Table 3 and Figure 2].

A strong association was observed between cardiac axis deviation and the presence of cardiac anomalies. Cardiac anomalies were detected in over two-thirds of fetuses with large axis and more than four-fifths with small axis, compared with < 1% among those with normal axis. This association was statistically highly significant [Table 4].

Cardiac axis deviation demonstrated high diagnostic performance for detecting cardiac anomalies, with high sensitivity and specificity and an excellent negative predictive value, indicating strong utility as a screening marker in anomaly scans [Table 5].

Pregnancy outcomes differed significantly according to cardiac anomaly status. Most fetuses without cardiac anomalies resulted in live births, whereas those with anomalies had high rates of medical termination and fetal or early neonatal loss, with very few live births. The difference in outcomes between groups was statistically significant [Table 6].

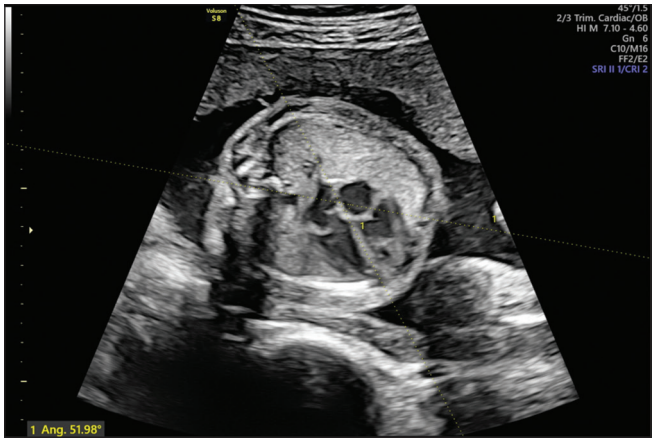

Figure 1: A case of normal cardiac axis measuring ~52° (normal range 45° ± 20°)

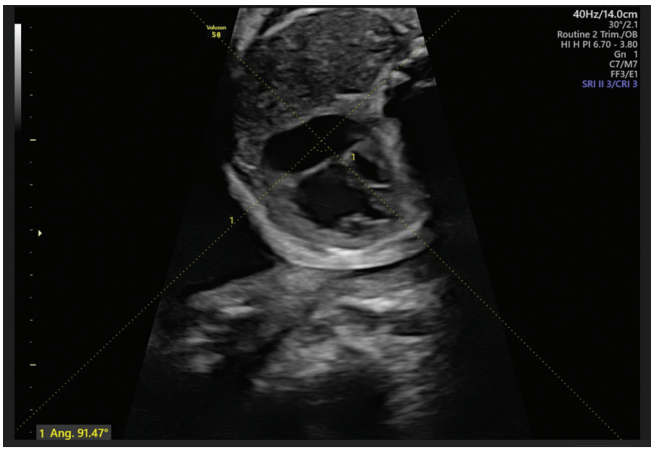

Figure 2: Left atrium and left ventricles appear atretic with levo-version. A case of hypoplastic left heart syndrome with an abnormal cardiac axis measuring ~91°

Table 1: Demographic and clinical characteristics of study population (*n*=810)

Parameter	Category	*n* (%)
Maternal age (years)	18–20	84 (10.4)
	21–30	268 (33.1)
	31–40	312 (38.5)
	41–45	146 (18.0)
	Mean±SD	31.82±8.19
Gestational age (weeks)	Mean±SD	20.32±0.85
Gravida	Primigravida	167 (20.6)
	Multigravida	643 (79.4)
Parity	Nulliparous	238 (29.4)
	Primiparous	242 (29.9)
	Multiparous	330 (40.7)
Referral indication	Routine anomaly scan	173 (21.4)
	Family history of cardiac disease	80 (9.9)
	Suspected fetal anomaly	73 (9.0)
	Maternal infection	71 (8.8)
	Advanced maternal age	69 (8.5)
	Multiple pregnancy history	68 (8.4)
	Abnormal screening test	67 (8.3)
	High-risk pregnancy	66 (8.1)
	Maternal diabetes	64 (7.9)
	Previous pregnancy anomaly	63 (7.8)

SD=Standard deviation

Table 2: Cardiac axis measurements and cardiac assessment findings (*n*=810)

Parameter	Category	Value, *n* (%)
Cardiac axis (°)	Large (>65)	46 (5.7)
	Normal (25–65)	746 (92.1)
	Small (<25)	18 (2.2)
	Mean±SD	45.05±10.2
Four-chamber view quality	Adequate	793 (97.9)
	Inadequate	17 (2.1)
Cardiac position	Normal	785 (96.9)
	Mesocardia	12 (1.5)
	Levocardia	10 (1.2)
	Dextrocardia	3 (0.4)
Heart size	Normal	802 (99.0)
	Cardiomegaly	8 (1.0)
Cardiac anomaly	Present	51 (6.3)
	Absent	759 (93.7)

SD=Standard deviation

Table 3: Spectrum of detected cardiac anomalies (*n*=51)

Cardiac anomaly type	*n* (%)
Septal defect (ASD + VSD)	12 (1.5)
Tetralogy of Fallot	7 (0.9)
Truncus arteriosus	6 (0.7)
Double outlet right ventricle	5 (0.6)
Coarctation of the aorta	4 (0.5)
Total anomalous pulmonary venous return	4 (0.5)
Ebstein anomaly	3 (0.4)
Pulmonary stenosis	3 (0.4)
Tricuspid atresia	3 (0.4)
Single ventricle	2 (0.2)
Transposition of the great arteries	2 (0.2)
Atrioventricular canal defect	1 (0.1)
Cardiomyopathy	1 (0.1)
Hypoplastic left heart	1 (0.1)

ASD=Atrial septal defect, VSD=Ventricular septal defect

Table 4: Association between cardiac axis category and cardiac anomalies (*n*=810)

Cardiac axis	Cardiac anomaly present, *n* (%)	No anomaly, *n* (%)	Total
Large (>65°)	31 (67.4)	15 (32.6)	46
Normal (25°–65°)	5 (0.7)	741 (99.3)	746
Small (<25°)	15 (83.3)	3 (16.7)	18
Total	51	759	810
P	<0.001		

Discussion

In the present study, cardiac axis deviation was found to have a strong association with cardiac anomalies, thus emphasizing the practical utility of the marker as an adjunct in the assessment of the fetus in the context of the anomaly scan. The high rates of cardiac anomalies in the context of both increased and decreased axis deviation, as compared to those cases in which the axis was found to be within the range of normal, also emphasize the practical utility of this relatively simple measurement of the fetal cardiac axis. These findings were consistent with those of Shipp *et al*., who found that 44% of those fetuses in which the cardiac axis was >57° had cardiac defects, including truncus arteriosus, Ebstein anomaly, coarctation of the aorta, and tetralogy of Fallot.[14]

Several previous studies have also emphasized the importance of axis deviation in the context of fetal screening, with Sinkovskaya *et al*. showing abnormal cardiac axis in 74.1% of fetuses with congenital heart defects and a better screening performance compared with nuchal translucency, tricuspid regurgitation, and ductus venosus flow abnormality.[12] Moreover, the positive predictive value of left axis deviation was found to be 76% for structural abnormalities by Smith *et al*., with the authors stressing the potential for missing clinically significant conotruncal lesions with the four-chamber view alone.[15] Wolter *et al*. have further demonstrated that fetuses with conotruncal anomalies such as double outlet right ventricle, truncus arteriosus, and tetralogy of Fallot always display significantly abnormal axis values during gestation.[16] Jung *et al*. have further demonstrated that abnormal cardiac axis in the first trimester of gestation has significant associations with both congenital heart disease and aneuploidy.[10]

The anomaly spectrum with axis deviation seen in this series, which is mainly driven by septal defects and conotruncal anomalies, is consistent with prenatal detection rates for previous research. Tongsong *et al*., in a study of a large second-trimester pregnancy population, demonstrated a sensitivity of 84%,

Table 5: Diagnostic performance of cardiac axis deviation for detecting cardiac anomalies

Diagnostic performance	Value (%)
Sensitivity	90.2
Specificity	97.6
Positive predictive value	71.9
Negative predictive value	99.3

Table 6: Pregnancy outcomes by cardiac anomaly status (*n*=810)

Outcome	No anomaly (*n*=759), *n* (%)	Anomaly present (*n*=51), *n* (%)
Live birth	726 (95.7)	2 (3.9)
Medical termination	21 (2.8)	38 (74.5)
IUFD	3 (0.4)	6 (11.8)
Stillbirth	5 (0.7)	1 (2.0)
Early neonatal death	0	4 (7.8)
Neonatal death	4 (0.5)	0
P	<0.001	

IUFD=Intrauterine fetal demise

a specificity of 91%, for axis deviation as a marker for cardiac anomalies, and showed that this measurement could be incorporated into routine anomaly scans without adding a significant time burden.[17] Lee *et al*. also showed that this measurement is useful for differentiating normal from abnormal axis angles, as seen with conotruncal anomalies such as transposition of the great arteries and truncus arteriosus.[18]

Differences in the pattern of distribution of anomalies in the prenatal and postnatal periods should be viewed cautiously. Population-based data collected and summarized by Hoffman and Kaplan suggest that the most common heart defect identified postnatally is the VSD, whereas there is a relatively high rate of detection of complex and outflow tract defects in the prenatal population, which is due to the better sonographic visibility of these defects.[19] Carvalho *et al*. showed that the assessment of cardiac axis, as part of the standard four-chamber approach, increases the rate of detection of conotruncal defects from 40% to 78% and described axis deviation as an early indicator prompting detailed outflow tract evaluation.[20]

An important additional observation relates to the correlation between cardiac axis deviation and extracardiac anomalies. Significant correlations have been noted with intrathoracic and abdominal wall defects, thus supporting the theory that deviation of the cardiac axis may not only be due to cardiac malformation but also to altered anatomy of the thorax and thus the position of the mediastinum. An abnormal cardiac axis was noted in 68% of fetuses with congenital diaphragmatic hernia, as described by Berg *et al*., due to mechanical displacement of the heart itself.[21]

The diagnostic performance characteristics showed very high sensitivity, specificity, and an exceptionally high negative predictive value, which is consistent with the results of previous studies. In a study involving a total of 5000 pregnancies, Comstock found a sensitivity of 78% and a specificity of 93% for the identification of significant heart defects based on abnormal cardiac axis determination.[22] These characteristics are affected by the training level of the operator and the types of lesions included. The strong rule-out value of a normal axis is clinically important, whereas deviation effectively identifies a subgroup warranting detailed fetal echocardiography and structured counseling. As emphasized by Martínez *et al*., counseling regarding the possibility of heart diseases and other associated conditions is necessary upon the identification of an abnormal cardiac axis.[23]

Standardization in technical procedures is crucial for the accuracy of the results obtained from the measurements. Galindo *et al*. showed high interobserver agreement if proper training and technique are used and recommended supervised use before independent use.[24] While the concept of measuring the axes is simple, accuracy requires the achievement of a true transverse four-chamber plane and consistency in the use of the reference lines.

Several limitations should be considered. The study was conducted at a single tertiary referral center with a higher anomaly prevalence than general screening populations, which may influence predictive values and limit generalizability. Not all live births had uniform postnatal cardiac confirmation, so minor lesions may have been missed. Measurements were limited to the mid-trimester window, and axis values may vary across gestation. Broader multicenter validation and gestation-specific reference standards are therefore desirable. Future work should also evaluate the integration of cardiac axis with other cardiac screening markers and advanced imaging techniques, such as STIC, to further optimize prenatal cardiac screening performance.

Conclusion

Cardiac axis measurement during second-trimester anomaly scanning demonstrated high sensitivity, specificity, and very high negative predictive value for detecting congenital cardiac anomalies in this study. Cardiac axis deviation showed a strong association with both cardiac and selected extracardiac anomalies, indicating its usefulness as a practical adjunct marker during routine fetal cardiac evaluation. Given that axis measurement is simple to perform on the standard four-chamber view and achieved a high technical success rate, it represents a feasible addition to anomaly scan assessment. Identification of an abnormal cardiac axis can prompt timely referral for detailed fetal echocardiography, targeted counseling, and appropriate perinatal planning. Conversely, a normal cardiac axis provides substantial reassurance in the majority of cases. Incorporating cardiac axis assessment into routine anomaly scan protocols may enhance prenatal suspicion and risk stratification for congenital cardiac defects.

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Conflicts of interest

There are no conflicts of interest.

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