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Research Article

Diagnostic Performance of Dual-Source CT Angiography Compared with Echocardiography in Pediatric Congenital Heart Disease

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ABSTRACT

Objective: The aim of this study was to assess the diagnostic performance and radiation dose of 128-slice dual-source computed tomography (DSCT) angiography in pediatric patients with congenital heart disease (CHD) and to compare its diagnostic accuracy with that of transthoracic echocardiography (TTE).

Methods: Fifty-seven pediatric patients (mean age: 34.1 months; range: 0.5-156 months; 25 males and 32 females; mean body weight: 10.3 kg) who underwent thoracic DSCT angiography and TTE for suspected or confirmed CHD were retrospectively evaluated. Surgical findings conventional catheter angiography, alone or in combination, served as the reference standard. Diagnostic performance metrics, including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy, were calculated. Agreement between imaging techniques and the reference standard was assessed using Cohen's kappa coefficient, and paired comparisons were performed using the McNemar test.

Results: A total of 199 cardiovascular anomalies were confirmed, including 67 intracardiac and 132 extracardiac abnormalities. Computed tomography (CT) angiography detected 193 anomalies (96.9%), whereas TTE detected 179 anomalies (89.9%). For CT angiography, sensitivity, specificity, PPV, NPV, and overall diagnostic accuracy were 96.9%, 99.9%, 99.0%, 99.6%, and 99.5%, respectively. The corresponding values for TTE were 89.9%, 99.6%, 96.8%, 98.8%, and 98.5%. CT angiography demonstrated significantly higher overall detection rates than TTE (P = 0.01). Subgroup analysis showed that TTE had higher sensitivity for intracardiac anomalies, whereas CT angiography demonstrated superior performance in identifying extracardiac vascular abnormalities.

Conclusion: Dual-source CT angiography enables highly accurate anatomical assessment in pediatric CHD while maintaining acceptable radiation exposure levels. Although echocardiography remains the first-line imaging modality, CT angiography represents a valuable complementary technique, particularly for evaluating extracardiac vascular anomalies.

Keywords: Congenital heart disease, CT angiography, low effective dose, pediatric cardiac imaging, radiation dose

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INTRODUCTION

Congenital heart disease (CHD) is among the most frequently encountered congenital anomalies worldwide and continues to represent an important cause of morbidity and mortality in pediatric populations. Precise delineation of cardiac and vascular anatomy is essential for optimal clinical management and surgical planning. Current international guidelines emphasize the importance of multimodality imaging approaches—including echocardiography, computed tomography (CT), and magnetic resonance imaging —for the comprehensive evaluation of congenital cardiovascular anomalies.[1,2]

Transthoracic echocardiography (TTE) is widely regarded as the first-line imaging modality for evaluating CHD because it is readily available, portable, and capable of providing real-time assessment of cardiac structure and hemodynamics without exposure to ionizing radiation.[3] However, echocardiography is highly dependent on operator experience and may be limited by inadequate acoustic windows, particularly when assessing extracardiac vascular structures such as the aortic arch, pulmonary arteries, and pulmonary venous connections.[4]

Historically, cardiac catheterization served as the reference method for detailed anatomical evaluation of congenital cardiovascular abnormalities. Nevertheless, because this technique is invasive and associated with radiation exposure, its role in diagnostic evaluation has gradually decreased in contemporary pediatric practice.[5,6]

Recent developments in multidetector CT, particularly dual-source CT technology, have significantly improved the non-invasive evaluation of congenital cardiovascular anomalies. High spatial resolution and rapid acquisition capabilities allow detailed visualization of complex cardiovascular anatomy even in infants and young children with relatively high heart rates.[6,7] Numerous studies have demonstrated the high diagnostic accuracy of CT angiography in patients with CHD and highlighted its usefulness in detecting extracardiac vascular abnormalities that may not be adequately evaluated by echocardiography alone.[8-11]

MATERIALS AND METHODS

Study Population

This retrospective study included pediatric patients younger than 13 years who underwent thoracic CT angiography for suspected or confirmed CHD. All patients also underwent transthoracic echocardiography. Surgical findings and/or conventional catheter angiography served as the reference standard. The study protocol was approved by the Bezmialem Vakıf University Institutional Ethics Committee (Date: 16.10.2018, Decision No: 19/245), and written informed consent was obtained from the parents or legal guardians of all participants.

CT Angiography Protocol

All CT examinations were performed using a dual-source CT scanner (Somatom Definition Flash, Siemens Healthcare). Imaging was performed with the patient in the supine position. Peripheral intravenous access (20-24 gauge) was established, and iodinated contrast material was administered using an automated injector at 0.5-2 mL/s, with an average dose of 2 mL/kg. Scan timing was determined using bolus tracking, with the region of interest (ROI) placed in the descending aorta. Image acquisition was initiated when attenuation reached 100 Hounsfield Unit (HU). The scan range extended from the thoracic inlet to the diaphragm. Scanning parameters included collimation 128 × 0.6 mm, gantry rotation time 0.28 s, pitch 3, tube voltage 80-100 kVp, and tube current 30-120 mAs, adjusted according to the patient's body size. All imaging data were analyzed on a dedicated workstation (Syngo.via, Siemens Healthcare) using vascular imaging software. All CT angiography examinations were reviewed by an experienced radiologist.

The radiation dose was estimated from the dose-length product values provided by the CT scanner. Because these values were calculated using a 32-cm phantom, they were multiplied by two to convert them to the 16-cm phantom equivalent recommended for pediatric dose estimation. Effective radiation dose was calculated using age-specific conversion factors for thoracic CT examinations.

Statistical Analysis

Statistical analyses were performed using SPSS (version 16.0; SPSS Inc., Chicago, IL, USA). Diagnostic performance metrics, including sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy, were calculated using surgical findings, conventional catheter angiography, or both as the reference standard. Agreement between imaging modalities and the reference standard was assessed using Cohen's kappa coefficient. Diagnostic performance parameters were calculated together with their corresponding 95% confidence intervals (95% confidence intervals). Paired comparisons between CT angiography and TTE for anomaly detection were performed using the McNemar test, and a P value < 0.05 was considered statistically significant.

RESULTS

A total of 57 children were included in the study. The demographic characteristics of the study population are summarized in Table 1.

Following TTE and CT angiography, 22 patients underwent conventional angiography, 28 patients underwent surgery, and 7

MAIN POINTS

- Dual-source computed tomography (CT) angiography demonstrated higher diagnostic sensitivity than transthoracic echocardiography in detecting congenital cardiovascular anomalies.
- CT angiography was superior in identifying extracardiac vascular abnormalities, such as major aortopulmonary collateral arteries, vascular rings, and pulmonary venous anomalies.
- Low-dose CT protocols allow for accurate diagnosis while maintaining acceptable radiation exposure in pediatric patients.

patients underwent both procedures; these procedures served as the reference standard for diagnostic evaluation. A total of 199 cardiovascular anomalies were confirmed by surgery and/or conventional angiography, including 67 intracardiac and 132 extracardiac anomalies.

CT angiography detected more anomalies than TTE, corresponding to detection rates of 96.9% and 89.9%, respectively. The detection rates of both imaging modalities are summarized in Table 2. The diagnostic performance parameters their corresponding 95% confidence intervals for CT angiography and TTE are presented in Table 3. CT angiography demonstrated higher overall sensitivity, specificity, and diagnostic accuracy compared with TTE. A paired comparison using the McNemar test showed that CT angiography detected significantly more anomalies than TTE ($P = 0.01$).

The subgroup analysis showed that TTE had higher sensitivity for intracardiac anomalies, whereas CT angiography had higher sensitivity for extracardiac vascular abnormalities (Table 3).

Table 1. Demographic Characteristics of the Study Population

Variable	*P* value
Number of patients	57
Male/female	25/32
Mean age (months)	34.1 ± 36.8
Age range (months)	0.5-156
Mean body weight (kg)	10.3 ± 7.9
Weight range (kg)	3-38

A representative example of a coronary artery anomaly associated with Tetralogy of Fallot, demonstrated by CT angiography, is shown in Figure 1. Examples of extracardiac vascular anomalies detected by CT angiography are illustrated in Figure 2.

Agreement analysis demonstrated excellent concordance between CT angiography and the reference standard ($\kappa = 0.974$, $P < 0.001$), whereas TTE demonstrated very good agreement ($\kappa = 0.929$, $P < 0.001$).

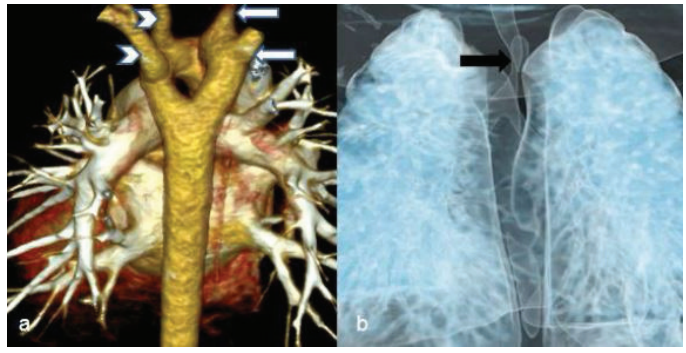


Figure 1. Coronary artery anomaly in a 2-year-old girl with Tetralogy of Fallot. Three-dimensional CT angiography (a) and maximum-intensity projection (MIP) images (b) demonstrate pulmonary artery stenosis (curved arrow) and the origin and proximal segments of the coronary arteries. A single coronary artery originates from the left sinus of Valsalva (black arrow), and the left anterior descending artery crosses the right ventricular outflow tract (white arrow).

CT, computed tomography.

Table 2. Detection of Intracardiac and Extracardiac Anomalies by Imaging Modality

Anomaly type	Total anomalies	Detected by TTE n (%)	Detected by CT angiography n (%)	*P* value
Intracardiac anomalies	67	67 (100)	61 (91.0)	**0.031**
Extracardiac anomalies	132	112 (84.8)	132 (100)	**< 0.001**
Total anomalies	199	179 (90.0)	193 (96.9)	**0.01**

P value < 0.05 was considered statistically significant.
CT, Computed tomography; TTE: Transthoracic echocardiography

Table 3. Diagnostic Performance of CT Angiography and TTE for Intracardiac and Extracardiac Anomalies

Parameter	CT Angiography % (95% CI)	TTE % (95% CI)	*P* value
Intracardiac anomalies			
Sensitivity	91.0 (82.0-96.3)	100 (94.6-100)	**0.031**
Extracardiac anomalies			
Sensitivity	100 (97.2-100)	84.8 (77.5-90.1)	**< 0.001**
Overall diagnostic performance			
Sensitivity	96.9 (93.4-98.8)	89.9 (84.9-93.5)	**0.01**
Specificity	99.9 (99.5-100)	99.6 (99.1-99.9)	-
Positive predictive value	99.0 (96.2-99.9)	96.8 (93.2-98.7)	-
Negative predictive value	99.6 (99.0-99.9)	98.8 (97.6-99.5)	-
Accuracy	99.5 (98.9-99.9)	98.5 (97.5-99.2)	-

P value < 0.05 was considered statistically significant.
CI, Confidence interval; CT, Computed tomography; TTE: Transthoracic echocardiography.

In addition to assessing cardiovascular abnormalities, CT angiography enabled the evaluation of thoracic structures and revealed airway compression caused by vascular anomalies in six patients, as illustrated in Figure 3. Findings consistent with heterotaxy syndrome were also identified in four patients.

Radiation dose parameters are summarized in Table 4. The mean effective radiation dose for CT angiography was 1.46 ± 0.39 mSv.

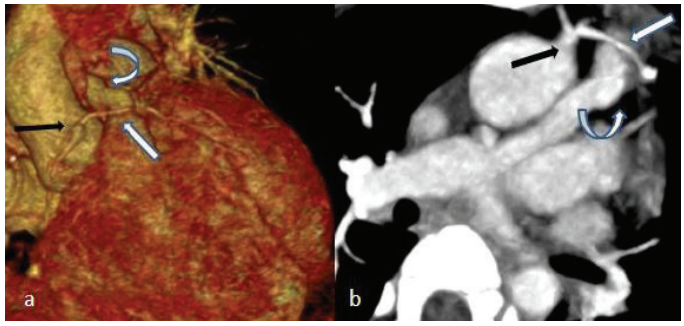


Figure 2. Partial anomalous pulmonary venous return in a 4-month-old girl. Three-dimensional CT angiography (a), a coronal maximum intensity projection (MIP) image (b), and axial CT images (c, d) demonstrate that the right inferior, left superior, and left inferior pulmonary veins drain into the vertical vein (black arrow), whereas the right superior pulmonary vein drains into the superior vena cava (white arrow). An associated atrial septal defect is also present.

LSPV, left superior pulmonary vein; RSPV, right superior pulmonary vein; SVC, superior vena cava; ASD, atrial septal defect; CT, computed tomography.

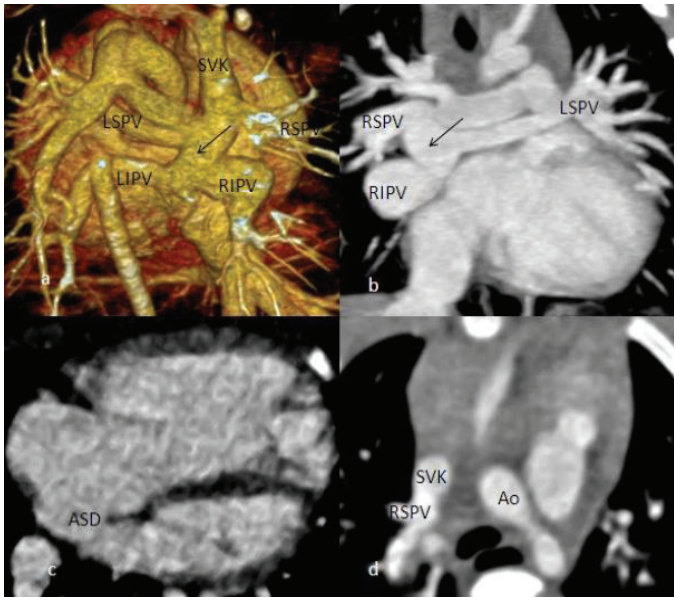


Figure 3. Double aortic arch causing vascular ring in a 1-year-old male patient. Three-dimensional CT angiography demonstrates bilateral aortic arches (a). Airway reconstruction images (b) show tracheal narrowing due to compression by the vascular ring.

CT, computed tomography

Table 4. Radiation Dose Parameters in CT Angiography

Parameter	*P* value
Mean dose-length product (DLP)	32.14 ± 8.97 mGy·cm
Effective dose range	0.88-2.5 mSv
Mean effective dose	1.46 ± 0.39 mSv
Mean effective dose (< 1 year)	1.71 ± 0.36 mSv

CT, Computed tomography.

DISCUSSION

Echocardiography continues to serve as the primary imaging modality for the initial assessment of CHD because it is widely available and enables real-time evaluation of cardiac morphology and hemodynamics without exposure to ionizing radiation.[3] However, previous studies have shown that echocardiography may be limited in the assessment of extracardiac vascular structures due to its dependence on acoustic windows and relatively limited spatial resolution.[4] These limitations are particularly relevant for patients with complex congenital cardiovascular anomalies who require comprehensive anatomical evaluation.

Historically, cardiac catheterization was considered the reference method for detailed anatomical assessment of congenital cardiovascular abnormalities. Nevertheless, because of its invasive nature and associated radiation exposure, its role in routine diagnostic evaluation has decreased in contemporary pediatric practice.[5,6] Consequently, non-invasive cross-sectional imaging techniques have become increasingly important in the diagnostic work-up of CHD.

Advances in multidetector CT technology, particularly the development of dual-source CT systems, have significantly improved the diagnostic capabilities of CT angiography. The combination of high spatial resolution and rapid acquisition enables detailed visualization of complex cardiovascular anatomy even in pediatric patients with elevated heart rates.[6,7] Furthermore, three-dimensional reconstruction techniques provide comprehensive anatomical information that may facilitate surgical planning and clinical decision-making.

Several studies have reported high diagnostic accuracy of CT angiography in patients with CHD. Reported diagnostic accuracy values generally range between approximately 95% and 99% for CT angiography, whereas echocardiography demonstrates diagnostic accuracies between 83% and 93%, particularly for extracardiac vascular anomalies.[8-11] In addition, Kravchenko et al.[12] demonstrated high diagnostic performance of dual-source CT angiography in pediatric patients with CHD, supporting the reliability of modern CT techniques for detailed anatomical assessment of complex cardiovascular anomalies.

The findings of this study are consistent with previous reports and indicate that CT angiography provides higher overall diagnostic accuracy compared with TTE. In our cohort, CT angiography detected more anomalies than TTE, and statistical analysis confirmed that the difference was significant.

A key finding of this study was the superior performance of CT angiography in detecting extracardiac vascular anomalies. Previous studies have consistently demonstrated

that CT angiography is particularly effective in identifying extracardiac abnormalities such as aortic arch anomalies, major aortopulmonary collateral arteries, and anomalous pulmonary venous connections.[8-11] Consistent with these findings, CT angiography detected all extracardiac anomalies in our cohort, whereas TTE failed to identify several clinically significant lesions.

Conversely, TTE demonstrated higher sensitivity for intracardiac abnormalities, particularly small septal defects. Similar observations have been reported in previous comparative studies evaluating CT angiography and echocardiography in CHD.[13-14] The relatively low sensitivity of CT angiography for small intracardiac defects may be related to the absence of electrocardiogram (ECG)-gated acquisition and their small size.

Another important advantage of CT angiography is its ability to simultaneously evaluate thoracic structures beyond the cardiovascular system. In the present study, CT imaging enabled the identification of airway compression caused by vascular anomalies and provided additional information regarding heterotaxy syndrome. Previous reports have also emphasized the value of CT imaging in evaluating thoracic structures outside the cardiovascular system.[15]

Radiation exposure remains an important consideration in pediatric CT imaging. However, recent technological advances, including high-pitch acquisition techniques, automated tube current modulation, and advanced reconstruction algorithms, have significantly reduced radiation doses in pediatric cardiac CT examinations. In previous studies, reported effective radiation doses for pediatric cardiac CT have ranged between approximately 1.0 and 5.0 mSv, depending on scanning protocols and patient characteristics.[15-20] In this study, the mean effective radiation dose was 1.46 mSv, which is within the lower range reported in the literature. These findings indicate that the dual-source CT protocol used in our study provides diagnostically adequate image quality while maintaining a relatively low radiation exposure compared with those reported in previously published studies.

Study Limitations

This study has several limitations. First, the relatively small sample size may limit the generalizability of the findings. In addition, the retrospective design and the wide age distribution of the study population may have influenced image quality and diagnostic performance. Image interpretation was performed by a single experienced radiologist; therefore, interobserver variability was not assessed. The absence of automatic tube current modulation and prospective ECG-gating may have limited further dose reduction and the optimal visualization of coronary artery anatomy. Future multicenter studies, including larger patient populations and optimized low-dose CT protocols, are needed to provide a more comprehensive assessment of the diagnostic role of CT angiography in pediatric CHD.[21]

CONCLUSION

Dual-source CT angiography provides highly accurate anatomical evaluation with acceptable radiation exposure in pediatric patients with CHD. While TTE remains the first-line imaging modality for intracardiac assessment, CT angiography offers superior visualization of extracardiac vascular anomalies. Therefore, CT angiography represents an effective complementary imaging technique, particularly in patients with complex congenital cardiovascular anomalies or inconclusive echocardiographic findings.

Ethics

Ethics Committee Approval: The study protocol was approved by the Bezmialem Vakıf University Institutional Ethics Committee (Date: 16.10.2018, Decision No: 19/245)

Informed Consent: Written informed consent was obtained from the parents or legal guardians of all participants.

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Declaration of Interests: The authors declared no conflicts of interest.

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