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RESEARCH ARTICLE

Retrospective Analysis of Cardiac CT Angiography Applications in Pediatric Cardiology Clinic: Single Center Experience

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ABSTRACT

Objective: Congenital heart disease (CHD) is one of the most common congenital anomalies worldwide, necessitating detailed imaging for accurate diagnosis and surgical planning. While transthoracic echocardiography (TTE) serves as the first-line imaging modality, it may be insufficient in evaluating complex intracardiac and extracardiac structures. Cardiac computed tomography angiography (CTA) has emerged as a valuable complementary technique in pediatric patients, offering high-resolution anatomical visualization with relatively low radiation exposure. This study aims to retrospectively assess the role of cardiac CTA in the anatomical evaluation and clinical management of pediatric patients diagnosed with CHD at a tertiary care center.

Materials and Methods: Pediatric patients who underwent cardiac CTA between January 1, 2021, and September 1, 2025, were retrospectively analyzed. Demographic data, clinical findings, radiation dose, and contrast volume were evaluated. Both intracardiac and extracardiac anomalies were examined in detail.

Results: A total of 1,337 pediatric patients (mean age: 3.89 years; 56% male) were evaluated using cardiac CTA. The most common diagnoses were coarctation of the aorta (7.87%), Tetralogy of Fallot (7.5%), and double outlet right ventricle (6.38%). CTA demonstrated high diagnostic accuracy in assessing critical anatomical features such as the spatial relationships of the great vessels, coronary anomalies, and abnormal venous connections.

Conclusion: Cardiac CTA facilitates detailed anatomical assessment in pediatric CHD patients, supporting surgical planning and improving clinical outcomes.

Keywords: Cardiac computed tomography angiography (CTA), congenital heart disease (CHD), pediatric cardiology

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INTRODUCTION

Congenital heart defects (CHDs) are among the most common birth defects, affecting approximately 0.8% to 1.2% of live births worldwide.[1,2] These malformations originate from the intracardiac structures, the great vessels, and extracardiac vascular abnormalities. The wide range of anatomical variations and differences in clinical course require a multidisciplinary imaging approach to the diagnosis and management of CHD.[3] The clinical spectrum of CHD is wide, ranging from newborn to adult and usually requires postoperative and long-term follow-up. Diagnostic accuracy varies depending on patient age, anatomic complexity, cardiac function, and history of preoperative treatment or surgery.[4]

Cardiovascular imaging is critical for primary diagnosis, followed by preoperative evaluation and surgical planning, and long-term postoperative patient follow-up. Transthoracic echocardiography (TTE) remains the primary noninvasive imaging method for congenital heart disease (CHD) and is

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used routinely for all cases.[5] It provides high-resolution visualization of intracardiac anatomy, particularly valvular function and myocardial contractility. However, in postoperative patients or those with complex anatomy, TTE can be limited due to suboptimal acoustic windows related to patient-specific characteristics. The diagnostic quality of TTE is also highly dependent on the experience of the operator. In addition, TTE is not highly sensitive for evaluating extracardiac structures, such as the distal aorta, the aortic arch and its branches, the pulmonary artery and its associated branches, the pulmonary veins, and the tracheobronchial tree.[6]

In the preoperative evaluation of patients undergoing surgery for CHD, additional imaging modalities are often required to provide anatomic information in addition to TTE. Conventional invasive cardiac catheterization (ICA) has historically been the gold standard for cardiac imaging, providing both hemodynamic and anatomic assessment.[7] However, ICA is now considered for selected cases due to its invasive nature, prolonged procedure time, risk of complications, and prolonged hospital stay. The use of ICA is also limited by its inability to assess airway pathology or extracardiac vascular structures.[8]

Technological advances in imaging have recently enabled the development of cardiac computed tomography angiography (CTA). CTA can now provide detailed anatomical visualization with significantly lower radiation doses and contrast volumes. CTA has been increasingly used in the diagnostic algorithm for CHD.[9] Multi-detector, ECG-gated CT, multiplanar, and 3D reconstructions have provided images with high spatial and temporal resolution. Advanced software applications provide high-quality imaging at reduced radiation doses, which is especially important in pediatric populations.[10] Surgical advances in cyanotic CHD have led to a significant increase in survival rates, hence the need for periodic evaluation of these patients and early detection of late postoperative complications. The comprehensive assessment of complex anatomical and functional changes following corrective or palliative surgery requires advanced imaging strategies.[11]

CTA facilitates rapid and detailed evaluation of postoperative anatomy, aiding in clinical decision-making. It provides essential information regarding recurrence, residual lesions, vascular stenosis, and extracardiac anomalies. In contrast to MRI, which often requires sedation, CT is frequently performed in pediatric patients without sedation, resulting in shorter hospitalization times and greater procedural safety, especially for infants and young children.

Although echocardiography retains its role as the primary imaging modality, in cases where it is insufficient, CTA provides critical and often decisive complementary data in both the pre- and post-operative periods.[12]

Accordingly, cardiac CT is increasingly being used in the evaluation of CHD. Modern CT systems provide higher image quality, lower radiation doses, and shorter scan times—establishing CTA as an indispensable component of contemporary CHD diagnostic algorithms, with high diagnostic value that directly influences clinical decision-making.[13]

The evaluation of CHD involves more than just the cardiac system. These patients often present with associated abnormalities involving the airways, peripheral vasculature, and lung parenchyma. Cardiac CTA allows accurate visualization of these structures. Airway compression can occur both preoperatively and postoperatively and is a significant contributor to morbidity and mortality. Conditions such as tracheal or bronchial compression due to abnormal vasculature, congenital tracheoesophageal anomalies, and dynamic airway collapse require accurate imaging.[14] In addition, lymphatic abnormalities are common in single-ventricle physiology, particularly after Glenn or Fontan procedures, and CTA plays an essential role in their diagnosis and follow-up.[15,16]

This study aimed to evaluate our patient population who underwent cardiac CTA in the preoperative and postoperative periods at our pediatric cardiac center, focusing on detailed anatomical characterization and the diagnostic value of CTA in the management of CHD.

MATERIALS and METHODS

Our study was a single-center, retrospective study. This study included patients who were evaluated with cardiac CT angiography at our pediatric cardiology clinic between January 1, 2021, and September 1, 2025. The study was designed in accordance with the principles of the Declaration of Helsinki and approved by the Ethics Committee of Health Sciences University, Basaksehir Cam and Sakura City Hospital (protocol code 2025-151, approved on June 25, 2025).

We included patients between the ages of 0 and 18 who underwent cardiac CT angiography. All participants initially underwent transthoracic echocardiography (TTE) as part of both diagnostic evaluation and routine follow-up. Complementary imaging techniques, such as computed tomography angiography (CTA), were also employed to achieve a more comprehensive anatomical analysis. Demographic information—including age, sex, height, weight, and body surface area (BSA)—was recorded, with BSA calculated using the Du Bois formula:

$$BSA = 0.007184 \times height^{0.725} \times weight^{0.425}$$

Cardiac CT imaging was conducted using a 640-slice single-source CT scanner (Aquilion ONE, GENESIS Edition; Canon Medical Systems, Otawara, Tochigi, Japan) featuring a wide 16 cm detector and employing the Adaptive Iterative Dose Reduction 3D Enhanced (AIDR 3D Enhanced) algorithm. A prospective ECG-gated approach was applied during a single cardiac cycle for all subjects. Images were obtained in Volume Axial mode (rotation time: 0.35 seconds; scan length: 80–120 mm), with tube current managed via automatic exposure modulation. To enhance iodine contrast-to-noise efficiency in pediatric imaging, tube current was modulated using automatic exposure control, and a reduced tube voltage of 80 kV was applied.

All patients received an intravenous bolus of iodinated contrast agent (Kopaq 300 mgI/mL; Onko&Kocsel Pharmaceuticals, Kocaeli, Turkey) at 1.5 mL/kg, followed by a 10–20 mL saline flush using a dual-head power injector (MEDRAD, Bayer HealthCare, Beek, Netherlands). The injection rate ranged from 0.7 to 0.9 mL/kg, adjusted according to catheter caliber and patient size. Undiluted contrast was used throughout. Scans were performed without breath-holding or sedation, and an experienced cardiac radiologist supervised all examinations. Imaging acquisition targeted the initial contrast passage through the cardiovascular structures, centering the acquisition window at 45% of the R–R interval in patients with heart rates exceeding 90 bpm. Scanning was paused during phases deemed non-essential. For each individual, the most motion-free cardiac phase closest to the predefined target was retrospectively selected by the radiologist.

Data were reconstructed at 0.5 mm slice thickness using a standard kernel and the AIDR 3D Enhanced algorithm. Post-processing included multiplanar reconstruction (MPR), maximum intensity projection (MIP), and 3D volume rendering (VR). Radiation dose metrics—including dose-length product (DLP), volumetric CT dose index (CTDIvol), and scanned anatomical area—were documented for every examination. The CTDI and DLP values referenced a 32 cm phantom, while effective dose (ED) was calculated by multiplying the DLP by a factor of 2 to adapt to a 16 cm phantom model. Conversion coefficients specific to neonates and infants (0.039 mSv/(mGy·cm)) were applied based on age group for accurate dose estimation. All CCTA procedures were performed by a pediatric cardiovascular radiologist with over 15 years of experience in congenital heart disease imaging.

CT angiographic evaluation was performed with a comprehensive and systematic approach in patients with CHD. The analysis included the assessment of major vascular anomalies, such as aortic disorders (vascular rings, coarctation, aortic arch anomalies, and patent ductus arteriosus), pulmonary artery anomalies (pulmonary sling), conotruncal anomalies, transposition of the great arteries, tetralogy of Fallot, and single-ventricle palliation. The systemic and pulmonary venous structures were evaluated in detail, including persistent left superior vena cava, interrupted inferior vena cava, and anomalous pulmonary venous return.

Coronary arteries were assessed for origin, course, and anomalies according to the Leiden Convention and modified Leiden Convention. Cardiac structures, including valves, pericardium (with emphasis on effusion and congenital absence), and outflow tracts (LVOT and RVOT), were carefully analyzed. The morphology and function of the aortic and pulmonary valves were included in the evaluation. Thoracic and extracardiac structures, such as the esophagus, trachea, and bronchi, were examined for compression, along with mediastinal masses, hematomas, and thymic morphology. Pulmonary findings, including hypoplasia, peribronchial thickening, bronchiectasis, atelectasis, emphysema, mosaic pattern, infiltration, pulmonary edema, and sequestration, were recorded. Pleural findings, such as effusion, thickening, and pneumothorax, were also documented.

Abdominal and systemic organ evaluations included hepatosplenomegaly, asplenia, polysplenia, hepatic hemangiomas, liver congestion, portal and hepatic vein thrombosis, and portal venous gas. Renal and renal collecting system pathologies were assessed. Skeletal findings, such as thoracic wall deformities, rib fractures, and vertebral anomalies, were included.

The aortic assessment included the following areas: ascending aorta, proximal and distal arch, isthmus, descending aorta, aortic annulus, sinotubular junction, and aortic root. Additional parameters, such as radiation dose, scan coverage, dose length product (DLP), and effective dose (ED), were documented. Demographic data, including date of birth, age, sex, height, weight, intubation status, and clinical condition, were documented for all patients. This comprehensive CT angiographic evaluation provided crucial anatomical and functional information to support accurate diagnosis and surgical planning in congenital heart disease.

Ventriculoarterial connection was defined as DORV if more than 50% of the aorta originated from the right ventricle. Great artery relationship was assessed as normal, D malposition, L malposition, side-by-side, or anterior-posterior. Ventricular septal defects (VSD) were evaluated as subaortic, subpulmonic, doubly committed, or remote. Outflow tract stenosis, atrioventricular valve abnormalities, and coronary artery abnormalities were considered present or absent.

In this study, the classification of coronary arteries was conducted according to the Leiden Convention and modified Leiden Convention. In the surgical classification, the sinus that does not face the pulmonary valve was designated as the "non-facing sinus." Based on this reference point, the sinus on the right side was labeled as "Sinus 1," and the sinus on the left side as "Sinus 2." This classification can be applied independently of the relative positions of the great arteries or the anatomical location of the aortic valve within the body. The surgical classification of coronary arteries begins with positioning in the non-facing sinus and orienting towards the pulmonary valve. Starting from Sinus 1, a counterclockwise order is followed, and the coronary arteries are coded as "L" for the left anterior descending artery (LAD), "Cx" for the left circumflex artery (LCx), and "R" for the right coronary artery (RCA). Detailed documentation was made for coronary arteries originating from different sinuses or from separate orifices within the same sinus.

In imaging modalities (CT, MRI, and TTE), the fundamental principles of the surgical classification were preserved, but adjustments were made to accommodate imaging perspectives. In this context, the physician was positioned in the non-facing sinus, with their back towards the pulmonary valve, observing the aorta from a cranial-to-caudal viewpoint. In this orientation, the right sinus was designated as "Sinus 1," and the left sinus as "Sinus 2." The naming of coronary arteries was adapted to a clockwise order to align with the imaging perspective.

Statistical Analysis

The statistical analysis of the data obtained in this study was performed using the Statistical Package for the Social Sciences (SPSS) software. Descriptive statistics were used to summarize demographic and clinical variables. Continuous variables were expressed as mean, standard deviation (SD), minimum, and maximum values, while categorical variables were presented as frequencies and percentages. The basic demographic and clinical data of the patients, such as age, gender, height, weight, body surface area (BSA), radiation dose, and contrast volume, were reported as mean, SD, minimum, maximum, and percentage distributions. The normality of all variables was assessed using the Shapiro-Wilk test. Additionally, the normal distribution of continuous variables was confirmed through histograms, skewness and kurtosis coefficients, and Q-Q (quantile-quantile) plots. For data that did not meet normality assumptions, the median, interquartile range (IQR), and minimum-maximum values were reported. All data were summarized using descriptive statistics after confirming appropriate normality assumptions, and the results were presented in tables. Additionally, the diagnostic accuracy of specific anatomical findings was evaluated using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and area under the curve (AUC).

RESULTS

This retrospective study analyzed the demographic and clinical characteristics of patients who underwent cardiac computed tomography angiography (CTA) in the Department of Pediatric Cardiology. A total of 1,337 patients who underwent CTA between January 1, 2021, and September 1, 2025, were included in the study.

Of the patients, 56% were male (n=754) and 44% were female (n=566). The mean age was 3.89 years (range: 0.1–13.9 years). The age group distribution was as follows: 0–2 years (n=774, 57.46%), 2–7 years (n=166, 12.32%), 7–12 years (n=146, 10.84%), and 12–18 years (n=261, 19.38%). The mean weight was 15.89 kg (range: 3.12–49.78 kg), with a mean weight percentile of 35.97% (range: 23.92–44.17). The weight standard deviation (SDS) was −0.36 (range: −0.52 to 0.87). The mean height was 102.8 cm (range: 55.24–160.9 cm), with a mean height percentile of 42.74% (range: 26.87–41.7%). The height SDS was −0.17 (range: −0.92 to 0.69). The mean BMI was 14.95 kg/m² (range: 9.87–21.94 kg/m²), with a BMI percentile of 30.34% (range: 21.32–68.7%) and a BMI SDS of −0.52 (range: −1.28 to 0.89). During CTA acquisition, the radiation dose was 1.32 mSv (range: 0.88–2.32), and the mean contrast volume was 15.28 mL (range: 5.12–23.4). General patient characteristics are summarized in Table 1.

The most common congenital heart defects observed in patients undergoing CTA were aortic hypoplasia/coarctation of the aorta (7.87%, n=106), tetralogy of Fallot (TOF) (7.5%, n=101), Fontan/Glenn stage evaluation (6.46%, n=87), double outlet right ventricle (DORV) (6.38%, n=86), ventricular septal defect (VSD) (6.98%, n=94), and transposition of the great arteries (TGA) (5.27%, n=71).

Other commonly detected anomalies included atrial septal defect (ASD) (4.16%, n=56), atrioventricular septal defect (AVSD) (4.53%, n=61), and pulmonary valve anomalies (3.49%, n=47). Rare anomalies included Ebstein's anomaly (1.04%, n=14), tricuspid atresia (3.12%, n=42), pulmonary atresia (1.78–2.08%, n=24–28), and truncus arteriosus (1.11%, n=15). The distribution of patients who underwent CTA is shown in Table 2.

Table 1. The baseline clinical characteristics

	n	%
Sex (male)	754	56
Age (years)	3.89 (0.1–13.9)	
0–2 years	774	57.46
2–7 years	166	12.32
7–12 years	146	10.84
12–18 years	261	19.38
Weight (kg)	15.89 (3.12–49.78)	
Weight (percentile)	35.97 (23.92–44.17)	
Weight (SDS)	-0.36 (-0.52–0.87)	
Height (cm)	102.8 (55.24–160.9)	
Height (percentile)	42.74 (26.87–41.7)	
Height (SDS)	-0.17 (-0.92–0.69)	
BMI kg/m²	14.95 (9.87–21.94)	
BMI (percentil)	30.34 (21.32–68.7)	
BMI (SDS)	-0.52 (-1.28–0.89)	
Contrast volume (cc)	15.28 (5.12–23.4)	
Radiation dose (mSv)	1.32 (0.88–2.32)	

SDS: Standard deviation score; BMI: Body mass index

The relationship between the great vessels and the presence of coronary anomalies is especially important when planning surgery for patients with DORV and TGA. The great vessel relationships in TGA and DORV patients were as follows: D malposition in TGA (87.3%, n=62) and DORV (33.7%, n=29); side-by-side great vessel arrangement in TGA (5.63%, n=4) and DORV (39.53%, n = 34); L malposition in TGA (2.81%, n=2) and DORV (12.79%, n=11); normal great vessel relationship in TGA (2.81%, n=2) and DORV (10.46%, n=9); and inversus arrangement in TGA (1.40%, n=1) and DORV (3.48%, n=3). Coronary anomalies were present in 45% of TGA patients and 33% of DORV patients. The most common coronary anomaly in both disease groups was the origin of the Cx from the RCA. Additionally, in DORV patients, arch hypoplasia (24.41%, n=21), interrupted aortic arch (9.30%, n=8), anomalous pulmonary venous return (16.27%, n=14), and persistent left superior vena cava (PLSVC) (12.79%, n=11) were observed. Ventricular septal defect (<1.5 mm) was detected in 22.09% (n=19) of cases. Coronary anomalies in both DORV and TGA patients were identified with high sensitivity and specificity using CTA. The main anatomical structures evaluated by CTA in DORV and TGA patients are shown in Table 3.

Coronary artery anomalies were identified in 20.79% (n=21) of TOF patients. In addition, APCA (<2 mm) was observed in 16.83% (n=17) and MAPCA (>2 mm) in 15.84% (n=16) of cases. The mean Nakata index was 315.72±139.43, McGoon ratio 1.79 ± 0.19. Mean pulmonary valve diameter was 8.51±1.59 mm, MPA was 9.31±2.12 mm, RPA 7.39±1.37 mm, and LPA diameter was 7.75±1.58 mm. Cardiac CTA demonstrated high sensitivity and specificity in detecting critical anatomical features such as coronary anomalies, MAPCA presence, and dimensions of pulmonary arteries and their branches, which are essential for TOF surgery. Detailed evaluation of great vessel relationships and coronary artery anatomy was performed in patients with TGA and DORV, as shown in Table 4.

DISCUSSION

Congenital heart defects are considered one of the most prevalent birth anomalies. Recent advances in both surgical techniques and medical management have markedly extended the survival of individuals with these conditions. Yet, this prolonged life expectancy has also brought about a higher incidence of related complications and a greater demand for follow-up surgical treatments over time.

Transthoracic echocardiography remains the most widely used and gold standard method for the diagnosis and follow-up of congenital heart disease. Although it provides high-resolution imaging, transthoracic echocardiography has several important limitations. It is often inadequate for evaluating extracardiac structures, which can complicate surgical planning. In addition, the quality of the images obtained can vary significantly with patient age, body habitus, and operator experience, which can lead to diagnostic problems. Conventional invasive angiography has long been considered the gold standard for both hemodynamic and anatomic assessment. However, its use has declined in recent years due to several disadvantages, including high radiation exposure, the need for contrast agents, invasive nature, and prolonged hospital stay. Due to advances in technology, CTA has become a valuable alternative, offering lower radiation doses, reduced contrast requirements, and the ability to acquire high-resolution images in a single cardiac cycle.

In recent years, the widespread adoption of electrocardiogram (ECG)-gated and low-dose computed tomography angiography has further increased the utility of this imaging modality. These techniques allow high-quality imaging even in pediatric patients with higher heart rates, significantly reducing the radiation dose. In our study, computed tomography angiography was performed using electrocardiogram-gated techniques, 80 kilovolts to lower radiation exposure, and low-volume contrast agents calculated based on body weight (cc/kg). This approach significantly reduced the need for sedation in our patients and shortened hospital stays, reflecting the benefits of modern imaging protocols.[17]

Table 2. Pediatric congenital heart defects in computed tomography angiography patients

Disease	n	%
Ventricular septal defect (VSD)	94	6.98
Atrial septal defect (ASD)	56	4.16
Patent ductus arteriosus (PDA)	32	2.38
Fallot tetralogy (TOF)	101	7.5
Transposition of the great arteries (TGA)	71	5.27
Coarctation of the aorta (CoA) / arcus hypoplasia	106	7.87
Pulmonary valve anomalies (including pulmonary stenosis)	47	3.49
Mitral valve defects (including mitral atresia)	44	3.27
Aortic valve anomalies (including aortic stenosis)	71	5.27
Double inlet left / right ventricle (DILV)(DIRV)	32	2.38
Double outlet right ventricle (DORV)	86	6.38
Tricuspid atresia	42	3.12
Hypoplastic left heart syndrome (HLHS)	32	2.38
Pulmonary atresia with ıntact ventricular septum (IVS PA)	24	1.78
Pulmonary atresia with VSD (VSD PA)	28	2.08
Truncus arteriosus (All types: Type I-IV, A4 vs.)	15	1.11
Interrupted aortic arch (IAA)	21	1.56
Total anomalous pulmonary venous return (TAPVR/TAPVD)	39	2.9
Partial anomalous pulmonary venous return (PAPVR)	41	3.04
Congenitally corrected TGA (ccTGA)	26	1.93
Aortic arch anomalies	26	1.93
Ebstein anomaly	14	1.04
Atrioventricular septal defect (AVSD)	61	4.53
Fontan / Glenn stages evaluation	87	6.46
Aortic arch anomalies	35	2.6
Coronary evaluation	47	3.49
Other	69	5.12

In this study, we evaluated the results of cardiac computed tomography angiography, which is increasingly used in our clinic for detailed anatomical assessment and surgical planning in complex congenital heart disease. Our findings support the use of computed tomography angiography as an essential modality for accurate anatomical definition and development of an effective surgical strategy in this complex patient population.

Transposition of the great arteries is among the most frequent cyanotic congenital heart conditions observed in the neonatal period. In such cases, identifying coronary artery anomalies is crucial for the safe planning and execution of arterial switch operations.[18] Coronary artery anomalies are significant factors that can significantly increase postoperative mortality and morbidity.[19] Therefore, accurate preoperative identification of the coronary anatomy is essential for surgical success. While transthoracic echocardiography is generally sufficient to assess the origin of coronary arteries, it has limitations in evaluating the distal course of these arteries and their relationship to perivascular tissue. As shown in our previous study, computed tomography angiography provides statistically significantly better detection of coronary artery anomalies in patients with transposition of the great arteries compared with transthoracic echocardiography. In this study, we also found that computed tomography angiography provided high specificity and sensitivity in evaluating the coronary arteries, which is consistent with similar findings reported in the literature. In addition, the spatial relationship between the great arteries is a critical factor in the surgical success of the Le-Compte maneuver and arterial transfer during the arterial switch operation. In our study,

Table 3. Essential CT angiography findings in DORV / TOF

	Anatomy	n	%	SNS (%)	SPS (%)	PPV (%)	NPV (%)	AUC (%)
DORV	Coronary anomalies	29	33.72	89	98	95	95	0.96
	Arcus hypoplasia	21	24.41	96	98	94	98	0.96
	Interrupted aortic arch	8	9.30	100	100	100	100	1.00
	APCA	15	17.44	95	98	93	98	0.95
	APVC	14	16.27	100	100	99	98	0.95
	PLSVC	11	12.79	100	100	100	100	1.00
	VSD (<1,5mm)	19	22.09	58	82	48	92	0.81
TOF	Coronary anomalies	21	20.79	85	98	89	95	96
	APCA (<2mm)	17	16.83	79	97	85	99	94
	MAPCA (>2mm)	16	15.84	91	99	92	99	97
	Nakata index (mm^2/m^2)	315.72±139.43						
	McGoon ratio	1.79±0.19						
	Pulmonary annulus diameter (mm)	8.51±1.59						
	Pulmonary annulus Z score	-1.15±1.58						
	Main pulmonary artery (MPA) diameter (mm)	9.31±2.12						
	Main pulmonary artery Z score	1.51±0.69						
	Right pulmonary artery (RCA) diameter (mm)	7.39±1.37						
	Right pulmonary artery (RCA) Z score	0.61±1.41						
	Left pulmonary artery (LPA) diameter (mm)	7.75±1.58						
	Left pulmonary artery (LPA) Z-score	1.09±1.12						

CT: Computed tomography; DORV: Double outlet right ventricle; TOF: Fallot tetralogy; SNS: Sensitivity; SPS: Specificity; PPV: Positive predicative value; NPV: Negative predicative values; AUC: Area under the curve; APCA: Aberrant pulmonary collateral artery; APVC: Anomalous pulmonary venous connection; PLSVC: Persistent left superior vena cava; VSD: Ventricular septal defect; MAPCA: Major aortopulmonary collateral arteries

the most common aortic malposition was D malposition, as reported in the literature. This was followed by L malposition and anterior-posterior positioning. These findings highlight the importance of accurately assessing the spatial relationships of the aorta during surgical planning.

Double outlet right ventricle is a complex congenital heart defect with surgical planning and timing highly dependent on its specific subtype.[20] In these patients, an optimal surgical strategy requires a thorough understanding of the relationship between the ventricular septal defect and the great arteries, as well as the 3D orientation of the great vessels and the presence of coronary artery anomalies.[21] In our study, coronary artery anomalies were identified in 32 (45%) of the patients with a double outlet right ventricle, a rate consistent with previous studies in the literature. The most common coronary artery anomaly in our series was the origin of the left circumflex artery from the right coronary artery, a finding frequently reported in other studies.[22] In addition, 21 (24%) of our patients with double outlet right ventricle had aortic arch hypoplasia, while 8 (9%) had an interrupted aortic arch. These findings underscore the importance of evaluating aortic arch morphology carefully during surgical planning. Accurate identification of these extracardiac pathologies may help surgeons anticipate potential perioperative complications and ultimately may improve patient outcomes.[23]

Tetralogy of Fallot is the most common cyanotic congenital heart disease and typically requires complete corrective surgery within the first year of life.[24] In these patients, the structure of the pulmonary arteries and their branches, the anatomical course of the coronary arteries, the presence of major aortopulmonary collateral arteries, and the presence of additional ventricular septal defects are critical for surgical planning.[25] Conventional angiography has traditionally been used to evaluate patients with Tetralogy of Fallot before surgery. This technique has long been the gold standard for hemodynamic and anatomical assessment. However, it has several significant disadvantages, including its invasive nature, the risk of catheter-related complications, high radiation

Table 4. Great vessel relationship/coronary artery origins TGA and DORV

	n	%
Relationship of the great vessels		
D-malpose		
TGA	62	87.3
DORV	29	33.7
Side-by-side		
TGA	4	5.63
DORV	34	39.53
L-malpose		
TGA	2	2.81
DORV	11	12.79
Normal		
TGA	2	2.81
DORV	9	10.46
Inversus		
TGA	1	1.40
DORV	3	3.48
Coronary artery origins		
Usual coronary artery (1LCx-2R)		
TGA	39	55
DORV	57	66.27
Unusual coronary artery		
TGA	32	45
DORV	29	33.72
1L-2RCx		
TGA	18	23.91
DORV	16	18.60
2LCxR		
TGA	7	9.85
DORV	8	9.30
1R- 2LCx		
TGA	5	7.04
DORV	2	2.32
1LR-2Cx		
TGA	2	2.8
DORV	1	1.16
1RCxL		
TGA	1	1.4
DORV	2	2.32

TGA: Transposition of the great arteries; DORV: Double outlet right ventricle; Cx: Circumflex coronary artery; L: Left anterior descending coronary artery; R: Right coronary artery

exposure, the need for large amounts of contrast media, and prolonged hospital stay. As a result, conventional angiography has been largely replaced in recent years by computed tomography angiography, which provides detailed anatomical information with less invasiveness, lower radiation doses, and reduced contrast requirements.[26] However, in certain special cases, such as when major aortopulmonary collateral arteries (MAPCAs) need to be embolized in the preoperative period, conventional invasive angiography may still be preferred. Outside of these special situations, computed tomography angiography is now widely used because of its lower risk of complications, shorter procedure time, and reduced contrast requirements. Both the literature and our study have shown that the results of conventional angiography and computed tomography angiography are comparable in patients with Tetralogy of Fallot.[27] Computed tomography angiography provides high sensitivity and specificity for evaluation of the pulmonary arteries and their branches, detection of coronary artery anomalies, and identification of major aortopulmonary collateral arteries. In addition, it provides detailed information on pulmonary artery diameters, branch angles, and lung parenchyma, which are critical for surgical planning.[28] In our study, 21 (21%) patients had coronary anomalies, 17 (16.83%) had anomalous pulmonary collateral arteries smaller than 2 mm (APCA), and 16 (15.84%) had main aortopulmonary collateral arteries larger than 2 mm (MAPCA). A conal coronary branch crossing the right ventricular outflow tract (RVOT) was the most common coronary anomaly. Similar findings have been reported in the literature, where conal coronary branches crossing the RVOT are the most commonly observed coronary anomalies in patients with Tetralogy of Fallot.[29] However, one of the major limitations of computed tomography angiography is its reduced sensitivity and specificity for detecting small ventricular septal defects, as it typically acquires images in a single cardiac cycle. Therefore, in cases where additional ventricular septal defects are suspected, it may be necessary to use complementary imaging modalities such as transthoracic echocardiography.

Prolonged mechanical ventilation and extended stays in the intensive care unit are not limited to patients with Tetralogy of Fallot; they are also seen in other cases of congenital heart surgery, often in association with aortopulmonary collateral arteries. In these patients, surgical intervention to close these collateral arteries may be necessary to enable successful ventilator weaning.[30] Computed tomography angiography is widely used to accurately identify extensive aortopulmonary collateral arteries in various congenital heart diseases, providing high sensitivity and resolution.

In addition, because the imaging field in computed tomography angiography includes the lung parenchyma, pulmonary abnormalities can also be accurately identified. In our study, the most common lung lesion detected was partial atelectasis, which was observed in 11% of patients. Similar findings have been documented in the literature, indicating that atelectasis is the most common extracardiac anomaly in patients with congenital heart disease.

An atrial septal defect is the most commonly identified congenital heart defect in adults, and it is often associated with partial anomalous pulmonary venous return. In adult patients, transthoracic echocardiography often provides suboptimal image quality, making computed tomographic angiography a preferred method for evaluating partial anomalous pulmonary venous return.[31] In our study, 43 patients had partial anomalous pulmonary venous return, 28 of whom also had large atrial septal defects, consistent with previous reports in the literature.[32]

Patients with single ventricle physiology often undergo multiple surgeries, and evaluating the pulmonary vasculature is essential before Glenn or Fontan procedures.[33] In our clinic, this evaluation is usually performed by computed tomography angiography because of its low radiation dose and reduced contrast requirements. In our study, 87 (6.5%) of the patients evaluated by cardiac computed tomography angiography were in this group. Similar findings have been reported in the literature, where computed tomography angiography is commonly used to evaluate single ventricle anatomy.[34]

Coronary artery anomalies may present with symptoms in the neonatal period or remain silent until adolescence, thus reflecting a broad clinical spectrum. For patients with potential coronary anomalies, computed tomography angiography is a highly sensitive evaluation method.[35] In our study, 47 (3.49%) of the patients underwent computed tomography angiography specifically to evaluate the origin and course of the coronary arteries. In addition, patients with myocarditis who have widespread myocardial infarction findings on physical examination or electrocardiogram are increasingly being evaluated with computed tomography angiography. Approximately half (22) of the patients in our study who underwent coronary evaluation had a history of myocarditis. Similar findings have been reported in the literature, where cardiac computed tomography angiography is frequently used for coronary evaluation in pediatric populations.[36]

In conclusion, computed tomography angiography is an essential adjunct to transthoracic echocardiography for the comprehensive evaluation of cardiac anatomy. While transthoracic echocardiography provides a highly accurate assessment of intracardiac structures, valves, and blood flow, computed tomography angiography provides superior visualization of extracardiac structures. The combined use of these two modalities is critical for optimal surgical planning and long-term clinical management of patients with congenital heart disease.

CONCLUSION

Cardiac computed tomography angiography (CTA) has proven to be an invaluable imaging modality for the detailed anatomical evaluation of pediatric patients with congenital heart disease (CHD). This study highlights the critical role of CTA in identifying complex cardiac and extracardiac anomalies, which are essential for accurate surgical planning and long-term patient management. With its ability to provide high-resolution, three-dimensional anatomical detail at relatively low radiation doses, CTA effectively complements transthoracic echocardiography, particularly in cases where conventional imaging methods may be insufficient. As the complexity of CHD varies widely, a personalized imaging approach that includes CTA can significantly improve surgical outcomes and enhance the quality of life for pediatric patients. Future research should continue to focus on optimizing radiation doses and contrast protocols to further expand the clinical applications of this powerful diagnostic tool.

Disclosures

Ethics Committee Approval: The study was approved by the University of Health Sciences, Basaksehir Cam and Sakura City Hospital Clinical Scientific Ethics Committee (No: 151, Date: 25/06/2025).

Informed Consent: Informed consent was obtained from all participants.

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