Koşuyolu Heart Journal

Koşuyolu Heart J 2025;28(3):100–106
DOI: 10.51645/khj.2025.524

Original Article

Comparison of Radiation Exposure between Computed Tomography Angiography and Invasive Catheter Angiography in the Pre-operative Assessment of Patients with Tetralogy of Fallot

Ali Nazım Güzelbağ,[1] Serap Baş,[2] Muhammet Hamza Halil Toprak,[1] Demet Kangel,[1] Burcu Çevlik,[1] Selin Sağlam,[3] İbrahim Cansaran Tanıdır,[1] Erkut Öztürk[1]

[1]Department of Pediatric Cardiology, University of Health Sciences, Başakşehir Çam and Sakura City Hospital, İstanbul, Türkiye

[2]Department of Radiology, University of Health Sciences, Başakşehir Çam and Sakura City Hospital, İstanbul, Türkiye

[3]Department of Anesthesiology, University of Health Sciences, Başakşehir Çam and Sakura City Hospital, İstanbul, Türkiye

Abstract

Objectives: Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart disease in infancy, frequently requiring early surgical repair. Detailed pre-operative imaging is essential for assessing cardiovascular and extracardiac anatomy to guide surgical planning. While conventional invasive catheter angiography (ICA) has traditionally been used for this purpose, computed tomography angiography (CTA) has emerged as a promising non-invasive alternative with lower risk, shorter procedure times, and reduced radiation exposure. Given the vulnerability of pediatric patients, optimizing radiation dose and understanding its determinants – such as body size – are critical. The objective of the study is to compare radiation exposure, contrast agent usage, and procedural duration between CTA and ICA in the pre-operative evaluation of TOF patients under 1 year of age and to evaluate the correlation between patient anthropometric measurements and radiation dose.

Methods: This retrospective single-center study included 120 TOF patients who underwent complete surgical repair between 2021 and 2024. Seventy-four patients underwent CTA and 46 underwent ICA. Data on radiation dose, contrast volume, and procedure time were collected. Correlations between effective dose and patient age, weight, height, and BMI were analyzed.

Results: CTA significantly reduced effective radiation dose (1.21±0.19 mSv) compared to ICA (5.28±1.71 mSv, p<0.01), required less contrast agent (8.02±2.38 cc vs. 38.8±13.01 cc), and had a shorter procedure time (3.1±0.58 min vs. 21.03±10.79 min; p<0.001). Radiation dose was positively correlated with weight (CTA: r=0.41, p=0.0006; ICA: r=0.52, p=0.0009), height (CTA: r=0.32, p=0.0012; ICA: r=0.24, p=0.0014), and BMI (CTA: r=0.35, p=0.0008; ICA: r=0.39, p=0.0053), while no significant correlation was observed with age.

Conclusion: CTA is a safe, non-invasive, and time-efficient imaging modality for the pre-operative evaluation of TOF patients, offering significant reductions in radiation dose and contrast use compared to ICA. The observed correlation between radiation dose and body size underscores the need for individualized imaging protocols in pediatric practice.

Keywords: Computed tomography angiography (CTA); invasive catheter angiography (İCA); tetralogy of Fallot (TOF).

Cite This Article: Güzelbağ AN, Baş S, Toprak MHH, Kangel D, Çevlik B, Sağlam S, et al. Comparison of Radiation Exposure between Computed Tomography Angiography and Invasive Catheter Angiography in the Pre-operative Assessment of Patients with Tetralogy of Fallot. Koşuyolu Heart J 2025;28(3):100–106

Address for Correspondence:
Ali Nazım Güzelbağ

Department of Pediatric Cardiology, University of Health Sciences, Başakşehir Çam and Sakura City Hospital, İstanbul, Türkiye

E-mail: anguzelbag@gmail.com

Submitted: May 26, 2025
Revised: September 08, 2025
Accepted: September 12, 2025
Available Online: December 16, 2025

Fallot Tetralojisi Tanısı Olan Hastaların Preoperatif Değerlendirmesinde Bilgisayarlı Tomografi Anjiyografi ile İnvaziv Kateter Anjiyografi Arasında Radyasyon Maruziyetinin Karşılaştırılması

Özet

Amaç: Bu çalışma, Tetralogy of Fallot (TOF) hastalarının preoperatif değerlendirilmesinde, bilgisayarlı tomografi anjiyografi (CTA) yönteminin invaziv kateter anjiyografi (İKA) ile karşılaştırıldığında daha güvenli, noninvaziv ve zaman açısından daha verimli olup olmadığını; ayrıca radyasyon dozu ile vücut ölçüleri arasındaki ilişkiyi değerlendirmeyi amaçlamaktadır.

Gereç ve Yöntem: Bu retrospektif, tek merkezli çalışmaya 2021–2024 yılları arasında tam cerrahi onarım uygulanan 120 TOF hastası dahil edildi. Yetmiş dört hastaya CTA, 46 hastaya ise İKA uygulandı. Radyasyon dozu, kontrast hacmi ve işlem süresi değerlendirildi. Etkin doz ile yaş, kilo, boy ve vücut kitle indeksi (VKİ) arasındaki korelasyon analiz edildi.

Bulgular: CTA, İKA'ya göre anlamlı düzeyde daha düşük radyasyon dozu (1,21±0,19 mSv vs. 5,28±1,71 mSv; p<0,01), daha az kontrast madde kullanımı (8,02±2,38 cc vs. 38,8±13,01 cc) ve daha kısa işlem süresi (3,1±0,58 dk vs. 21,03±10,79 dk; p<0,001) ile sonuçlandı. Radyasyon dozu; kilo (CTA: r=0,41; IKA: r=0,52), boy (CTA: r=0,32; IKA: r=0,24) ve VKİ (CTA: r=0,35; IKA: r=0,39) ile pozitif korelasyon gösterdi (tüm p<0,01). Yaş ile anlamlı bir ilişki saptanmadı.

Sonuç: CTA, TOF hastalarının preoperatif değerlendirmesinde İKA'ya göre daha düşük radyasyon ve kontrast maruziyeti ile güvenli, noninvaziv ve zaman açısından avantajlı bir seçenektir. Radyasyon dozu ile vücut ölçüleri arasındaki ilişki, pediatrik görüntülemede kişiye özel protokollerin önemini vurgulamaktadır.

Anahtar sözcükler: Bilgisayarlı tomografi anjiyografi (CTA); invaziv kateter anjiyografi (ICA); fallot tetralojisi (TOF).

Introduction

The most common cyanotic congenital heart disease in childhood is tetralogy of Fallot (TOF). It is characterized by anterior malalignment of the ventricular septum, a ventricular septal defect (VSD), obstruction of the right ventricular outflow tract (RVOT), an overriding aorta, and right ventricular hypertrophy.[1] TOF accounts for 7–10% of congenital heart defects requiring surgical repair in infants, with a reported prevalence rate of 3–5/10,000 live births.[2] Patients with TOF may present with severe cyanotic spells before surgical intervention. The presence of different anatomical subtypes requires a detailed anatomical assessment to guide treatment planning. This comprehensive evaluation often requires additional imaging modalities. The timing of surgical repair for TOF is determined by a multidisciplinary approach that carefully weighs the benefits and risks of early versus delayed intervention to achieve the optimal outcome based on the individual clinico-anatomical characteristics of all patients.[3,4]

Recent advances in surgical techniques and perioperative care have improved outcomes, making early total repair a viable and advantageous option for most patients with TOF. Due to the potentially life-threatening nature of cyanotic episodes, which are among the most common pre-operative symptoms, total repair is generally recommended within the first 6 months of life.[5] However, in selected patients with complex anatomy, a staged repair strategy may be considered.[6,7]

While transthoracic echocardiography (TTE) remains the first-line imaging modality for congenital heart disease,[8] it may not be sufficient for the evaluation of extracardiac pathology. A thorough pre-operative anatomical evaluation, including the pulmonary and coronary arteries and other major cardiopulmonary structures, is essential.[9] Historically, this has been accomplished by invasive cardiac catheterization. Nonetheless, the inherently invasive nature of catheter-based angiography – accompanied by potential complications including infection, hemorrhage, vascular trauma, and infrequent mortality – has prompted a growing interest in safer and less invasive diagnostic approaches.[10]

Advancements in imaging technology have significantly contributed to the growing adoption of computed tomography angiography (CTA), which offers high-resolution imaging while minimizing both contrast agent requirements and radiation exposure. Owing to its non-invasive nature, rapid acquisition times, and minimal patient discomfort, CTA is particularly advantageous in pediatric and high-risk populations. The introduction of multidetector CT systems and sophisticated image reconstruction methods has further enhanced its capacity to deliver detailed visualization of both cardiac and extracardiac anatomy, thereby supporting critical surgical planning.[11] In contrast to traditional invasive angiography, CTA offers superior visualization of pulmonary and coronary arteries, as well as distal pulmonary vasculature, while markedly minimizing the procedural risks and patient discomfort inherent to catheter-based technique.[12]

Recent evidence supports the use of CTA as a dependable and noninvasive modality for pre-operative assessment in patients with TOF, serving as a viable substitute for traditional cardiac catheterization angiography. In addition, CTA allows for accurate identification of major aortopulmonary collateral arteries (MAPCAs) and vascular compressions on the tracheobronchial structures, which contributes to improve surgical planning.[13,14] With all these consideration factors, cardiac CTA has become an alternative to ICA for the pre-operative assessment of TOF patients due to its recent advances in image quality, reduced radiation exposure, lower contrast requirements, minimally invasive nature, and reduced need for hospitalization.

In this study, we compared the radiation doses of conventional catheter angiography, which has been used traditionally, and CTA, which has been increasingly used in recent years, for the pre-operative assessment of TOF patients.

Materials and Methods

Our study was a single-center, retrospective study. This study was conducted by the Declaration of Helsinki and approved by the Ethics Committee of Istanbul Çam and Sakura City Hospital, University of Health Sciences of Türkiye (Protocol Code: 2025/117 and Date: May 14, 2025). Informed consent was not required, as the study was conducted retrospectively.

The study encompassed typical TOF cases who received complete surgical correction before 12 months of age, within the period from January 2021 to January 2025. All patients underwent TTE as part of their clinical evaluation throughout the diagnostic and follow-up period. To provide a detailed pre-operative anatomical assessment, additional imaging methods were performed, including CTA and conventional catheter angiography (CCA).

To ensure a more uniform study population and to minimize risks associated with prolonged procedure time during conventional angiography, we excluded patients with complex anatomy, significant comorbidities, or those requiring additional procedures beyond the standard protocol during angiography. Patients were excluded if they were older than 1 year, had TOF with associated atrioventricular septal defects or hypoplastic ventricles, had undergone previous palliative cardiac procedures, demonstrated impaired renal function, were deemed unsuitable for surgical correction, or had significant comorbid medical conditions.

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 s; scan length: 80–120 mm), with tube current managed through 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 350 mgI/mL; Onko&Kocsel Pharmaceuticals, Kocaeli, Türkiye) 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. For pediatric patients requiring sedation, intravenous midazolam (0.05–0.1 mg/kg) and/or fentanyl (1–2 mcg/kg) were administered by a cardiac anesthetist under continuous monitoring. Patients were monitored throughout the procedure with pulse oximetry, electrocardiography, and blood pressure monitoring. Recovery was supervised until patients returned to baseline neurological status. 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, maximum intensity projection, and 3D volume rendering. 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 the 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. For this pediatric cohort under 12 months of age, ED calculations were performed using the conversion factor of 0.039 mSv/(mGy·cm) specific to neonates and infants.[15,16] All CCTA procedures were performed by a pediatric cardiovascular radiologist with over 15 years of experience in congenital heart disease imaging.

Cardiac catheterization procedures were completed under general anesthesia through femoral vascular access using the Philips® AZURION 7 B12 biplane imaging system (Philips Medical Systems, Eindhoven, Netherlands). Sedation was administered intravenously using midazolam and/or fentanyl under the supervision of a cardiac anesthesiologist when required. Adequate hydration was ensured before and after the procedure, and renal function was evaluated before and after catheterization. Hemodynamic data, including intracardiac pressures and oxygen saturation levels, were recorded from multiple cardiac chambers, the aorta, and the vena cava using fluid-filled catheters. Angiocardiographic imaging was performed using an intravenous bolus of iodinated contrast agent (Kopaq 350 mgI/mL; Onko&Kocsel Pharmaceuticals, Kocaeli, Türkiye) at a dosage not exceeding 4 mL/kg. To evaluate the RVOT, pulmonary artery morphology, and contractile function, right ventricular angiography was performed using anteroposterior projection with cranial angulation and a left anterior oblique view. For left ventricular assessment, including chamber size, function, presence and location of VSDs, and degree of aortic override, angiographic imaging was obtained in the left anterior oblique projection with cranial tilt. Aortic root angiography was utilized to determine the laterality of the aortic arch, identify major aortopulmonary collateral vessels, and measure the diameter of the descending thoracic aorta at the level of the diaphragm. Pulmonary venous return was visualized during the levo-phase, and selective right coronary angiography was conducted to verify its anatomical origin and to detect any branches that traverse the RVOT. Radiation dose metrics were reported for each procedure by the Philips® Artis biplane system, categorized by fluoroscopy alone and Image acquisition. Invasive catheterization procedures were carried out by a pediatric cardiologist with over 10 years of clinical experience in the field of congenital heart disease. Both fluoroscopic imaging and cine acquisition were performed at a frame rate of 15 frames/s. The system incorporated automated dose regulation and spectral beam filtration to optimize image quality while minimizing radiation exposure. Radiation dose parameters – including total fluoroscopy time (minutes), air kerma (mGy), and dose-area product (DAP; µGy·m^2) – were systematically documented. Air kerma, recorded at a standardized reference point in air, was used as a proxy for entrance skin dose, whereas DAP represented the cumulative radiation delivered, calculated by multiplying instantaneous air kerma by the irradiated field area. For invasive coronary angiography (ICA), radiation exposure was quantified using air kerma-area product (PKA) sensors embedded in the X-ray tube assembly, with cumulative dose values expressed in PKA units (Gy·cm^2). Effective doses for coronary CT angiography (CCTA) and ICA were estimated using validated conversion coefficients (0.014 mSv/mGy·cm for CCTA DLP and 0.018 mSv/Gy·cm^2 for ICA PKA), in line with manufacturer guidelines and published standards. EDs for cardiac CTA were calculated using the age-appropriate conversion coefficient of 0.039 mSv/mGy·cm for DLP values. For ICA, EDs were estimated using the conversion factor of 0.018 mSv/Gy·cm^2 for PKA values, in line with published standards.

All catheterization and angiographic datasets were evaluated independently by a cardiologist who was blinded to the corresponding CTA and echocardiographic results.

Radiation Dose Metrics

In this study, radiation dose parameters were separately recorded and analyzed for CTA and invasive coronary angiography (ICA), utilizing modality-specific dosimetric indicators.

For CTA, three main dose metrics were assessed:

CTDIvol (mGy): Indicates the average absorbed radiation exposure per unit volume in the scanned region, automatically provided by the CT system.

DLP: Represents the total radiation dose delivered over the entire scan length and is calculated as DLP = CTDIvol × scan length.

ED, mSv: Represents the radiation dose adjusted for tissue sensitivity and biological risk and is derived from DLP using a conversion coefficient (ED=DLP×k, where k=0.014 mSv/mGy·cm for chest CTA).

For ICA, performed with fluoroscopic imaging, the following metrics were used:

DAP (Gy·cm^2): The total energy delivered to the patient is calculated by multiplying the absorbed radiation dose by the area exposed to irradiation.

Air kerma (mGy): Quantifies the radiation energy transferred to a reference point near the patient's skin and is used to assess the risk of skin injury.

ED, mSv: Estimated from DAP using a standard conversion factor (ED=DAP×k, with k=0.2 mSv/Gy·cm^2 for coronary angiography).

In our study, we compared the radiation exposure associated with cardiac CTA and invasive angiography.

Statistical Analysis

Continuous data were reported as mean values with corresponding standard deviations (mean±SD), while categorical data were presented as percentages. The distribution of the data was tested for normality using the Shapiro–Wilk test. Statistical evaluation of demographic and clinical features between the CTA and ICA cohorts was conducted using the independent t-test for data with normal distribution and the Mann–Whitney U test for non-parametric variables. Categorical variables were analyzed using either the Chi-square test or Fisher's exact test, depending on the data distribution and sample size. To assess the relationship between effective radiation dose and patient anthropometric parameters (age, weight, height, and BMI), Pearson correlation analysis was used. Correlation coefficients (r) and corresponding p-values were reported. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). P<0.05 was considered statistically significant.

Results

A total of 120 patients with TOF were included in the study. Of these, 74 patients were evaluated preoperatively with cardiac CTA and 46 patients were evaluated with conventional invasive angiography (ICA). Baseline demographic and clinical characteristics were similar between the two groups (p>0.05). The general characteristics of the patients are shown in Table 1.

In patients who were evaluated preoperatively using CTA, the mean DLP was 24.52±4.68 mGy-cm, the ED was 1.21±0.19 mSv, and the CTDIvol was 2.52±0.56 mGy. The mean contrast volume used during the procedure was 8.02±2.38 cc, the procedure time was 3.1±0.58 min, and the fluoroscopy time was 23.12±8.34 s. In patients preoperatively evaluated with ICA, the mean ED was 5.28±1.71 mSv, the air kerma was 37.3±13.5 mGy, and the DAP was 3.12±0.97 cGy-cm^2. The mean contrast volume was 38.8±13.01 cc, the procedure time was 21.03±10.79 min, and the fluoroscopy time was 273.87±161.59 s. The mean procedure time was significantly shorter in the CTA group compared to the ICA group (3.1±0.58 min vs. 20.73±11.12 min; p=0.00032). Similarly, contrast volume (8.02±2.38 cc vs. 39.2±14.07 cc; p=0.00074) and ED (1.21±0.19 mSv vs. 5.28±1.71 mSv; p=0.0024) were significantly lower in the CTA group. Radiation dose and procedural differences between CTA and ICA are shown in Table 2.

In addition, the ED showed a statistically significant positive correlation with patient weight, height, and BMI in both groups. In the CTA group, the correlations were weight (r=0.41, p=0.0006), height (r=0.32, p=0.0012), and BMI (r=0.35, p=0.0008). In the ICA group, these correlations were weight (r=0.52, p=0.0009), height (r=0.24, p=0.0014), and BMI (r=0.39, p=0.0053). There was no significant correlation between age and ED in either group (CTA: p=0.271; ICA: p=0.546). Significant correlations between ED and patient

Table 1. The baseline clinical characteristics

	Mean±SD	p
Sex (male), (%)		
CTA	54	0.847
ICA	58	
Age (month)		
CTA	5.81±2.15	0.635
ICA	5.47±1.98	
Weight (kg)		
CTA	7.12±3.05	0.579
ICA	7.45±2.98	
Weight (percentile)		
CTA	31.23±18.72	0.432
ICA	39.62±11.63	
Weight (SDS)		
CTA	0.17±1.23	0.318
ICA	0.22±1.27	
Height (cm)		
CTA	65.81±15.42	0.732
ICA	66.34±14.23	
Height (percentile)		
CTA	31.18±21.13	0.321
ICA	34.78±17.23	
Height (SDS)		
CTA	-0.36±1.17	0.489
ICA	-0.24±0.98	
BMI kg/m^2		
CTA	15.8±3.35	0.579
ICA	16.74±2.37	
BMI (percentile)		
CTA	31.63±19.74	0.258
ICA	35.89±18.76	
BMI (SDS)		
CTA	-0.29±1.19	0.643
ICA	-0.14±1.37	
Saturation (Spo_2)		
CTA	87.32±6.41	0.587
ICA	85.68±5.7	

SD: Standard deviation; CTA: Computed tomography angiography; ICA: Invasive catheter angiography; BMI: Body mass index.

Table 2. Procedural parameters and radiation exposure CTA and ICA

CTA (computed tomography angiography)	
DLP (dose length product, mGy·cm)	24.52±4.68
ED (effective dose, mSv)	1.21±0.19
CTDIvol (computed tomography dose index, mGy	2.52±0.56
Contrast volume (cc)	8.02±2.38
Procedure duration (minutes)	3.1±0.58
ICA (invasive catheter angiography)	
ED (effective dose, mSv)	5.28±1.71
Air Kerma (mGy)	37.3±13.5
DAP (dose-area product, cGy·cm²)	3.12±0.97
Contrast volume (cc)	38.8±13.01
Procedure duration (minutes)	21.03±10.79
Fluoroscopy time (seconds)	273.87±161.59

ED: Effective dose.

Table 3. Correlation between patient characteristics and effective dose of ICA/CTA

	Correlation coefficient (r)	p
ICA		
Age (month)	-0.113	0.546
Weight (kg)	0.52	0.0009
Height (cm)	0.24	0.0014
BMI kg/m^2	0.39	0.0053
CTA		
Age (month)	-0.204	0.271
Weight (kg)	0.41	0.0006
Height (cm)	0.32	0.0012
BMI kg/m^2	0.35	0.0008

BMI: Body mass index; CTA: Computed tomography angiography; ICA: Invasive catheter angiography.

weight, height, and BMI were shown in both CTA and ICA groups. These associations are shown in Table 3. Four patients (10%) who underwent CCA experienced access point complications (hematoma), while none of the patients in the CTA group experienced any procedure-related complications.

Discussion

This study compared CTA and CCA imaging methods used in the pre-operative evaluation of patients diagnosed with TOF in terms of radiation dose, contrast agent usage, and procedural duration. Comprehensive assessment of pulmonary artery branches, pulmonary vasculature, coronary artery anomalies, and aortopulmonary collaterals is critical for optimal surgical planning in TOF patients. Conventionally, these anatomical structures have been visualized through invasive catheter angiography. However, in recent years, technological advances have introduced noninvasive techniques that provide lower radiation doses, reduced contrast agent usage, and shorter procedure times.[17] Previous studies have also reported that invasive cardiac catheterization results in significant radiation exposure in pediatric patients. In the study by Rassow et al.,[18] the EDs during cardiac catheterization in pediatric patients were significantly higher. Similarly, in our study, significantly higher radiation exposure was also reported in the CCA group.

In our study, effective radiation dose showed a statistically significant positive correlation with patient weight, height, and BMI in both groups. The strongest correlation was observed with weight in both the CTA group (r=0.41, p=0.0006) and the ICA group (r=0.52, p=0.0009). These results suggest that body size, especially weight, has a marked effect on radiation exposure. Interestingly, no significant correlation was found between patient age and ED in either group, highlighting the importance of individualized dose optimization based on anthropometric parameters rather than age alone. Deak et al.[19] showed that the use of age- and sex-specific conversion factors can provide a more accurate estimate of the ED. These findings underscore the importance of developing patient-specific protocols. Similarly, Huda et al.[20] detailed the formulas and conversion factors used to accurately estimate ED in cardiac CT applications. The dose calculation methods used in our study are consistent with the standards recommended in the literature.

Protocols and dose reduction strategies used in pediatric cardiac CT are critical to ensuring safe imaging in children. A comprehensive review by Young et al.[21] detailed techniques to minimize radiation exposure and standardized clinical practice in this area. We implemented a low-dose CTA protocol with results consistent with published literature. Ben-Sadd et al.[22] reported the use of dual-source CT to obtain both high image quality and low radiation dose in 110 infants with congenital heart disease. In our study, similar protocols allowed for detailed anatomical characterization. Our protocols similarly enabled detailed anatomical characterization with high image quality at low EDs. Similarly, Duan et al.[23] found that high image quality was achieved in children with TOF using dual-source CT and manual bolus tracking, with a mean radiation dose of approximately 0.4 mSv.

The mean effective radiation dose was significantly lower in the CTA group compared to the CCA group (1.21±0.19 mSv vs. 5.28±1.71 mSv, $p<0.01$). This finding is consistent with multiple previous studies. Watson et al.[24] reported that non-gated thoracic CTA in pediatric patients delivered significantly less radiation compared to diagnostic cardiac catheterization (0.74 mSv vs. 10.8 mSv; $p<0.0001$), with this difference being even more pronounced in children under 1 year of age. Similar results were demonstrated by Aupongkaroon et al.[25] in adult patients, where CTA required significantly lower doses than CCA (2.88 mSv vs. 5.61 mSv). Shirin et al.[26] also showed that 64-slice CT systems have high diagnostic accuracy in congenital heart disease and can be an effective alternative to invasive angiography. Furthermore, Meinel et al.[27] reported that in TOF cases complicated by pulmonary atresia and MAPCAs, CTA yielded comprehensive anatomical visualization while delivering substantially lower radiation doses than CCA (0.9 mSv vs. 14.4 mSv). The relatively smaller dose difference in our study can be attributed to the strict implementation of the ALARA (As Low As Reasonably Achievable) principle at our institution.[28]

Our study also found that both procedure time and contrast volume were significantly less in the CTA group compared with the CCA group. The mean procedure time was 3.1±0.58 min for CTA and 21.03±10.79 min for CCA; the contrast volume was 8.02±2.38 cc and 38.8±13.01 cc, respectively ($p<0.001$). These differences are clinically significant, especially in pediatric patients with impaired renal function, and may be crucial in the choice of imaging modality.

Vascular access-related complications occurred in 4 patients (10%) undergoing CCA, all of which manifested as localized hematomas. Although these hematomas resolved spontaneously within a few days, they resulted in prolonged hospitalization in all affected patients. In contrast, no procedure-related complications were noted in the CTA group. This observation aligns with prior research showing that hematoma is one of the most frequent complications following femoral access in cardiac catheterization and is associated with increased hospital stay.[29] These findings further support the use of CTA as a safer and less invasive imaging alternative in pediatric patients.

Despite all these advantages, it should be noted that CCA remains an indispensable method in specific clinical scenarios. Invasive cardiac catheterization may be particularly beneficial for MAPCA closure procedures in patients suspected of having predominantly MAPCA-dependent pulmonary circulation. In addition, coronary artery assessment on CTA can be challenging in pediatric patients due to small vessel caliber and cardiac motion artifacts, making ICA valuable for detailed coronary artery evaluation when coronary anomalies are suspected. Therefore, ICA should be considered the preferred approach in patients with complex coronary anatomy, suspected MAPCA-dependent circulation requiring intervention, or when precise hemodynamic assessment is crucial for surgical planning. CCA also remains essential in cases requiring hemodynamic evaluation or assessment of complex anatomical variants. Therefore, the choice of imaging modality should be individualized based on the patient's clinical condition, anatomical complexity, and specific therapeutic requirements.

Limitation

This study has several limitations. First, the study was conducted as a single-center retrospective study, which may limit the generalizability of the findings. Despite using standardized conversion coefficients, radiation dose estimations may still vary depending on individual patient characteristics and institutional protocols.

Conclusion

CTA is a safe, noninvasive, and time-efficient imaging modality for the pre-operative evaluation of TOF patients. Compared to invasive catheter angiography (CCA), CTA significantly reduces radiation exposure, contrast agent usage, and procedure time. The strong correlation observed between radiation dose and patient anthropometric parameters – particularly weight, height, and BMI – highlights the importance of personalized imaging protocols in pediatric practice. While CCA remains essential for complex anatomical and hemodynamic assessments, CTA should be prioritized as the first-line imaging tool in standard TOF cases.

Disclosures

Ethics Committee Approval: The study was approved by the Istanbul Çam and Sakura City Hospital, University of Health Sciences of Türkiye Ethics Committee (no: 2025/117, date: 14/05/2025).

Informed Consent: Informed consent was obtained from all participants.

Conflict of Interest Statement: All authors declared no conflict of interest.

Funding: The authors declared that this study received no financial support.

Use of AI for Writing Assistance: No AI technologies utilized.

Author Contributions: Concept – A.N.G., S.B., E.Ö., M.H.H.T., D.K.; Design – A.N.G., S.B., E.Ö., D.K., B.Ç.; Supervision – A.N.G., S.B., E.Ö., M.H.H.T., D.K.; Resource – A.N.G., S.B., E.Ö., İ.C.T., D.K.; Materials – A.N.G., S.B., E.Ö., M.H.H.T., B.Ç.; Data collection and/or processing – A.N.G., S.B., E.Ö., D.K., B.Ç.; Data analysis and/or interpretation – A.N.G., S.B., E.Ö., M.H.H.T., B.Ç.; Literature search – A.N.G., S.B., E.Ö., İ.C.T., S.S.; Writing – A.N.G., S.B., E.Ö., İ.C.T., S.S.; Critical review – A.N.G., S.B., E.Ö., İ.C.T., S.S.

Peer-review: Externally peer-reviewed.

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