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RECOMMENDATIONS / *Cardiac imaging*

Pediatric cardiac computed tomography angiography: Expert consensus from the *Filiale de Cardiologie Pédiatrique et Congénitale (FCPC)* and the *Société Française d'Imagerie Cardiaque et Vasculaire diagnostique et interventionnelle (SFICV)*

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Abbreviations: ACAOS, anomalous origin of coronary artery from opposite sinus of Valsalva; ALCAPA, anomalous origin of the left coronary artery from pulmonary artery; ARCAPA, an anomalous origin of right coronary artery from pulmonary artery; BPM, beats per minute; CCTA, cardiac computed tomography angiography; CHD, congenital heart disease; ECG, electrocardiogram; HU, Hounsfield unit; MAPCAS, major aorto-pulmonary collateral arteries; MIP, maximum intensity projection; MPR, multiplanar reconstructions; MRI, magnetic resonance imaging; TTE, transthoracic echocardiogram.

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KEYWORDS
Computed tomography (CT);
Cardiac imaging techniques;
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Congenital heart disease;
Radiation dose

Abstract This article was designed to provide a pediatric cardiac computed tomography angiography (CCTA) expert panel consensus based on opinions of experts of the *Société Française d'Imagerie Cardiaque et Vasculaire diagnostique et interventionnelle (SFICV)* and of the *Filiale de Cardiologie Pédiatrique Congénitale* (FCPC). This expert panel consensus includes recommendations for indications, patient preparation, CTA radiation dose reduction techniques, and post-processing techniques. The consensus was based on data from available literature (original papers, reviews and guidelines) and on opinions of a group of specialists with extensive experience in the use of CT imaging in congenital heart disease. In order to reach high potential and avoid pitfalls, CCTA in children with congenital heart disease requires training and experience. Moreover, pediatric cardiac CCTA protocols should be standardized to acquire optimal images in this population with the lowest radiation dose possible to prevent unnecessary radiation exposure. We also provided a suggested structured report and a list of acquisition protocols and technical parameters in relation to specific vendors.

Introduction

In pediatric patients with congenital heart disease (CHD), cardiac computed tomography angiography (CCTA) has enhanced the applicability of cross-sectional anatomical imaging and is now used widely as a diagnostic complementary tool to echocardiography, cardiac magnetic resonance imaging (MRI), and cardiac angiography. However, regarding patient with CHD, adapted protocols can be formulated for the specific indication through applying general principles in CT acquisition and contrast administration. Individual modalities have specific attributes for assessment of CHD, but no single imaging method is comprehensive in any given patient. Therefore, clinicians must recognize the limitations of each imaging technique and endeavor to use a multimodality approach. CCTA can be used to obtain isotropic volume data, and high-quality two- (2D) and three- dimensional (3D) multiplanar reformatted images can be created to accurately and systematically delineate the normal and pathologic morphologic features of the cardiovascular system. CCTA may be technically challenging and demanding in uncooperative young children. Recent technical developments in CCTA, notably with decreasing radiation dose, have resulted in improved patient medical care. Therefore, pediatric cardiac CCTA protocols should be standardized to acquire optimal images in this population with the lowest possible radiation dose to prevent unnecessary radiation exposure [1].

We propose a pediatric CCTA consensus based on data from available literature (original papers, reviews and guidelines) and opinions of a group of experts from the *Société Française d'Imagerie Cardiaque et Vasculaire diagnostique et interventionnelle* (SFICV) and the *Filiale de Cardiologie Pédiatrique Congénitale* (FCPC). This expert panel consensus includes recommendations for indications, patient preparation, CTA radiation dose reduction techniques,post-processing techniques, a list of acquisition protocols and technical parameters in relation to specific vendors and a suggested structured report (Fig. 1).

Patient preparation

Careful patient preparation is a prerequisite for successful performance of pediatric CCTA. The patient should be quiet and relaxed. Infants should be comfortably placed in a specially designed bed with a blanket and bands to limit motion and provide warmth. Electrocardiogram (ECG) electrodes are placed on the chest outside the exam zone to avoid artifact. Exam and breath holding should be explained to children. Parents may stay with their child during imaging with proper protection against radiation exposure. The use of a power injector is preferred to manual injection of contrast media, as patients need to have a good injection site (antecubital vein, foot or head). For children < 6 years, to keep calm, it is recommended to perfuse a child a few hours before the CCTA. It is recommended to apply Emla (Anesdermg®, Laboratoire Pierre Fabre) patch at the puncture site one hour before perfusion. To obtain optimal vascular enhancement in subjects with superior cavopulmonary connection, leg vein injection is recommended. For imaging of total cavopulmonary connection or Fontan pathway, simultaneous injection of contrast agent through arm and leg veins should be preferred. General anesthesia is not necessary if newborns and infants could drink their baby bottle before exam to fall asleep. Teenagers and children

Structured report

First Name, Last Name:
Date of birth:
Identification number:
Examination date:

1. Indication:
- Age at the date of the CCTA
- Clinical context
- Question

2. Technique:
- CCTA date of commissioning
- Acquisition technique
- Contrast material volume and rate of injection, contrast name
- Heart rate
- Premedication
- DLP (mgy.cm)

3. Results:
- Image quality
- Segmental analysis
- Heart
  - Situs abdominal (when possible) solitus or inversus
  - Situs atriales olitus or inversus or ambiguus
  - Levo/dextro/meso- cardia
  - Systemic veins (connection, stenosis, anatomy)
  - Atrio-ventricular connection, ventriculo-arterial connection
  - Cardiac chambers
- Great vessels
  - Aorta (right or left, supra-aortic vessels, size, coarctation, injury, other)
  - Pulmonary arteries (size, stenosis)
  - Post-surgical anatomy (conduit, stent, other)
- Arteriosus ductus (presence or not, size, course)
- Coronary
  - Location of coronary ostia
  - Course
- Stenosis / aneurysm (size, location)
  - Diameter (aneurysm, fistula)
  - Dominance (if possible)
- Pericardium
- Thrombus
- Mediastinum / lung / esophagus / trachea
- Associated other malformation (bone or other)

4. Conclusion:
Synthetic answer to the question

Figure 1. Figure shows suggested structured report for cardiac computed tomography angiography in pediatric patients.

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older than 6 years are typically able to keep calm and follow instructions provided by staff. For younger children, light sedation may be occasionally required according to the pediatric cardiologist's or the pediatric anesthetist's practice. In rare situations for which general anesthesia is necessary, pre-anesthesia classical evaluation should be scheduled prior to CCTA.

CCTA techniques

A variety of CT techniques can be used to investigate children with CHD. Non-ECG-gated helical CT scanning and retrospectively ECG-gated CT scanning are likely to be replaced by prospectively ECG-triggered sequential CT scanning or one-shot acquisition. The scan length is defined according to clinical indication, and is limited to the heart for coronary indications or extended to the whole thorax for vascular anatomy studies. Precise acquisition parameters should be adapted locally depending on the available CT scanner model (Tables 1—6). The main difficulty of cardiac CCTA is that the cardiac phase with the lowest coronary artery motion is strongly dependent on the heart rate and is specific to each vessel [2,3]. A biphasic injection of iodinated contrast (270—300 mg of iodine/L < 40 kg, 320—350 mg of iodine/L > 40 kg), followed by a saline flush (1cc/kg) is injected using a power injector. The amount of iodinated contrast material is based upon the weight of the patient and varies from 1.5 to 2 cc/kg. Acquisition timing should not be automated but be decided by the operator according to the indication and the specific condition of the patient.

ECG-gated prospective acquisition

An ECG-gated prospective cardiac image acquisition is recommended in children [4,5]. It is applicable to any heart rate condition and even in free breathing. Beta-blockers could be used, not to decrease the heart rate but to stabilize it, especially in children over 4 years old.

First, antero-posterior and lateral scout views of the chest are performed, for both acquisition planning and dose modulation. It is recommended to use a field of view adapted to the pediatric population. A manual exposure window and target phase is selected prior to the scan according to heart rate and heart rate variability. Low heart rate (< 70) and high heart rate (> 120) tend to be less variable and a target phase of 75% and 40% of cardiac cycle respectively is recommended [6]. An exposure window is often not necessary in these patients. For patients with heart rates between 75 and 120 BPM and for those with high heart rate variability, it is often difficult to preview the right target phase an exposure window to 200—400 ms is recommended to provide a reconstruction window from 30% to 80% of the R—R cycle. During the acquisition, a 0.5 mm × 80 rows volume is acquired every one to three heartbeats: one beat for the acquisition the next beats for table motion. Multiples volumes are acquired to cover the entire heart, and automatic adaptive blending is used to stitch the scanned volumes into one reconstructed volume dataset. Kv should be selected as low as possible for the machine and the patient, and mA are adapted according to the patient weight. Based on prospectively ECG-triggered examinations, automated algorithms have been developed to determine the optimal cardiac phase in a short prospective multiphasic acquisition [7—9]. Its clinical efficacy has been demonstrated in tachycardia patients as well as in pediatric patients while keeping radiation doses low [8,9].

One shot acquisition

One shot acquisition allows acquiring the whole heart within one rotation, resulting in no step artifacts. The target phase should be chosen as previously described for general prospective acquisition protocols. Kv and mAs should be set as low as possible.

Iterative reconstruction and motion correction software

Iterative reconstruction algorithms and specific post-treatment software reducing coronary motion artifacts should be used when available [6,10—23].

Dose reduction

Minimizing radiation exposure is crucial in children with CHD, who may be exposed to multiple irradiating procedures throughout their lifetime. The choice of scanning protocol should be made based on and tailored to the patient's clinical characteristics such as heart rate, heart rate variability, weight, and thorax morphology. The Kv and mAs should be adapted to the patient morphology. Dose modulation during acquisition must be used if available. Moreover, all vendors developed several reconstruction algorithms that allow lowering radiation dose. All these techniques should be combined to lower radiation dose.

Post-processing

Reconstruction kernel

Over the past decade, post-processing imaging has rapidly evolved to perform accurate image reconstruction while keeping scan dose to a minimum. The reconstruction kernel affects image quality due to the tradeoffs between spatial resolution and noise for each kernel. A smooth kernel generates images with low noise but with reduced spatial resolution. A sharp kernel generates images with higher spatial resolution while increasing noise [24,25].

Due to the wide variety of clinical situations requiring pediatric cardiac CCTA, specific attention must be paid to the selection of reconstruction kernel. Smooth kernels should be used for native structures to reduce image noise and enhance low contrast detectability, whereas sharper kernels should be used in case of stents, metallic devices, or prosthetic valves [26,27]. The modulation of slice thickness and the settings of standard reconstruction kernels differ considerably among different vendors [28].

Windowing

Low tube voltage, commonly used for pediatric cardiac CCTA, leads to a different image aspect if the window

Table 1 Aquilion^{TM} (Canon Medical Systems) 64 section acquisition parameters.

Heart rate (BPM)	30–180
ECG synchronisation	Prospective
Weight (kg)	Any weight until 50
kVp	80
mA	200
Exposure window (ms)	200–400
Collimation (mm)	0.5 × 80
Target phase (%)	59
Rotation time (ms)	0.35
Field of view (mm)	180–240
Slice thickness and interval (mm)	0.5–0.25
Reconstruction algorithm	Iterative reconstruction (AIDR 3D)
Motion correction algorithm	PhaseExact (best phase)

BPM: beats per minute; AIDR: adaptative iterative dose reduction; 3D: three dimensional; ECG: electrocardiogram. First, antero-posterior and lateral scout views of the chest are performed. These are used for both planning and dose modulation. The wide-volume target cardiac computed tomography angiography acquisition is a dedicated scan mode for pediatric electrocardiogram-triggered CT examination. The target cardiac computed tomography angiography scan mode is designed to guarantee a low dose acquisition even in pediatric patients with a high heart rate. Manual exposure window and target phase are selected prior to CT acquisition. Multiples volumes are acquired to cover the entire heart and automatic adaptive blending is used to stitch the scanned volumes into one reconstructed volume dataset.

Table 2 Aquilion One^{TM} Genesis (Canon Medical Systems) one shot acquisition parameters.

HR (BPM)	30–180
ECG synchronisation/acquisition	Prospective target auto/one shot acquisition/one beat
Weight (kg)	Any weight until 50 kg
kV	80
mA	mA modulation (SURE Exposure)
Exposure window (ms)	200–400
Collimation (mm)	0.5 × 240 to 0.5 × 320 (adapted to the heart volume)
Target phase (%)	Auto target phase (75% if HR < 70 BPM and 40% if HR > 70 BPM
Rotation time (ms)	275
Field of view (mm)	240
Slice thickness (mm)	0.5
Reconstruction algorithm	Iterative
Motion correction algorithm	PhaseExact (best phase)

HR: heart rate; BPM: beats per minute; ECG: electrocardiogram. The one shot acquisition allows acquiring the whole heart within one single rotation. The exposure window of 200–450 ms is recommended to provide a reconstruction window from 30% to 80% of the R–R cycle.

setting is not adapted, mainly because of increased attenuation of high-density structures. Wider and higher window settings may minimize this effect and correct the image noise appearance [29,30]. Images are commonly processed with standard soft-tissue (*e.g.*, width, 400–450 Hounsfield units [HU]; level, 40–50 HU) and lung (*e.g.*, width −1,600 to −1,800 HU; level, −450 to −550 HU) window settings [31].

Multiplanar reconstructions

Interpretation of cardiac CCTA traditionally starts with review of the images obtained in the axial plane. Due to the wide variety of clinical situations and anatomies, pediatric cardiac CCTA often requires multiplanar reconstructions (MPR) or specific volume and kinetic rendering techniques.

2D MPR images can be generated in any plane with resolution similar to that of axial images. Coronal and sagittal images provide information about cardiovascular structures, and more particularly for structures that traverse the z-axis, that may not be apparent on axial images [32]. This method is therefore directly dependent on the slice thickness and overlap. In order to improve image quality, axial CCTA images should be reconstructed using thin reconstructed sections overlapped by at least 50% [32–41].

Curved MPR enable the 2D display of the complete course of a vessel in a single image by fitting a surface along the vessel center-line to assess maximum diameters, length or stenosis, or along the central bronchi to assess vascular airway compression [35]. A drawback of the curved MPR technique is that only a single branch can be displayed at a time [32]. Comprehensive review may require a more

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Table 3 Revolution™ CT (General Electric Healthcare) one shot acquisition parameters.

HR (BPM)	Any heart rate
ECG synchronisation/acquisition	Prospective/Axial cardiac
Weight (kg)	up to 50 kg
kV max	70—80
mA	Smart mA 150—450
Exposure window (s)	0.25—0.5
Collimation (mm)	160
Target phase (%)	40—50% if HR > 70 BPM/75% if < 70 BPM
Rotation time (s)	0.28
Field of view	Small
Slice thickness (mm)	0.625
Reconstruction algorithm	ASIR 40%
Motion correction algorithm	Freeze if HR variation

HR: heart rate; BPM: beats per minute; ECG: electrocardiogram; ASIR: adaptive statistical iterative reconstruction. Prospective ECG-triggered axial technique should be performed within a single rotation by single-source 512-section CT using a wide collimation detector (160 mm). Iterative reconstruction algorithm (Asir-V with 40% strength) and specific reconstruction software reducing coronary motion artifacts (SnapShot Freeze) are used.

Table 4 Revolution™ Discovery™ (General Electric Healthcare) acquisition parameters.

HR (BPM)	< 70			≥ 70		
ECG synchronization	Prospective			Prospective		
Weight (kg)	< 40	40—60	> 60	< 40	40—60	> 60
kV max	80	80	100	80	80	100
mA	160	350	450	160	350	450
Collimation (mm)	64 × 0.625	64 × 0.625		64 × 0.625	64 × 0.625	64 × 0.625
Exposure window (padding ms)	0—200	200	200			0—200
Target phase (%)	75	75	75	40	40	40
Rotation time (ms)	0.35			0.35		
Field of view	Adapted to patient morphology			Adapted to patient morphology		
Slice thickness (mm)	0.625			0.625		
Reconstruction algorithm	Iterative reconstruction ASIR 60%			Iterative reconstruction ASIR 60%		
Motion correction algorithm	Freeze (if HR variation)			Freeze (if HR variation)		

HR: heart rate; BPM: beats per minute; ECG: electrocardiogram; ASIR: adaptive statistical iterative reconstruction. The step-and-shoot (SAS) acquisition is used. Radiation is delivered during the selected cardiac phase and padding is recommended.

integrated approach. Two post-processing techniques are detailed below: maximum intensity projection (MIP) and volume rendering.

MIP images

MIP consists of projecting the voxel with the highest attenuation value on every view throughout the volume onto a 2D image [36]. A single volumetric parameter from the original data is used to reconstruct customizable images. This method tends to display bone and contrast material-filled structures preferentially, making it a particularly suitable adjunct for the study of heart structures and large vessels. Thus, MIP is widely used in pediatric CCTA due to simple and easy use. MIP sections of variable thicknesess are helpful to assess the size and location of vessels, including the coronary arteries. As a limitation, however, the depth and occlusion information cannot be perceived on MIP images, leading to confounded spatial relationships [37].

Volume rendering

Volume rendering defines the optical properties of voxel attenuation values encountered along the ray. A specific color is assigned to the attenuation value of each voxel. The results vary according to the segmented area, the selected color, opacity, and lighting settings, so that they are not currently standardized [32]. Volume rendering is sensitive to image noise, thereby it is recommended to increase slice thickness to improve image quality with no increase in radiation dose [38]. Volume rendering gives an overview of the anatomy of the whole heart, with particularly detailed visualizations of hyperattenuating objects, including contrast-enhanced vessels and highly vascularized structures [39]. A number of studies have highlighted the

Table 5 Somatom® Definiton Flash, Drive and Force (Siemens Healthineers) dual source CCTA acquisition parameters.

Heart rate (BPM)	Any heart rate	> 70 bpm < 70 bpm
ECG Synchronization/acquisition	Sequential	Prospective
Weight (kg)	< 20	> 20
kV max	70	80
mA	250	450
Exposure window	—	—
Collimation (mm)	64 × 0.6	64 × 0.6
Target phase (%)	40	40—75
Rotation time (ms)	0.28	0.28
Field of view	Pediatric	Pediatric
Slice thickness (mm)	0.6	0.6
Reconstruction algorithm	Iterative	Iterative
Motion correction algorithm	—	—

BPM: beats per minute; ECG: electrocardiogram. Helical high pitch mode or sequential prospective acquisition with padding is used to provide a reconstruction window from 30 to 80% of the R—R cycle depending of the heart rate. Care dose4D is deactivated when weight < 20 kg and activated when weight > 20 kg. Care KV is deactivated. kV and mA are based upon the weight.

Table 6 iCT and Ingenuity (Philips Healthcare) acquisition parameters.

Heart rate (BPM)	Any heart rate
ECG synchronization/acquisition	Prospective
Weight (kg)	Up to 50
kV max	80
mA	Auto DoseRight index
Exposure Window (ms)	180 (iCT)—266 (Ingenuity)
Collimation (mm)	64 × 0.625 (iCT)128 × 0.625 (Ingenuity)
Target phase (%)	40
Rotation time (ms)	270 (iCT)—400 (Ingenuity)
Field of view (SFOV)	50—500
Slice thickness (mm)	0.625 (effective slice thickness, 0.8)
Reconstruction algorithm	Iterative (Model Based IMR)
Motion correction algorithm	Edge correction

BPM: beats per minute; ECG: electrocardiogram; IMR: iterative model reconstruction. Step-and-Shoot acquisition is used. Radiation is delivered during the selected cardiac phase (40% if HR > 70 bpm, 75% if heart rate < 70 bpm).

accuracy of volume rendering in various applications such as vascular stenosis [40] and the production of realistic images suitable for referring physicians or surgeons [42—44]. This technique is also useful for 3D-printing, computational modeling, and virtual computed procedures [45—48]. Novel techniques, such as cinematic rendering, are emerging to produce photorealistic images but without pediatric application at this time [7].

Cine CT

Cine CT is not recommended in children and echocardiography or cardiac MRI are preferred. Indeed, radiation exposure increases substantially without current tube modulation during the acquisition [31,43]. Although functional cardiac assessment with CT is highly concordant with cardiac MRI and improves diagnostic accuracy for patients with complex anatomy [48,49], non-radiating techniques should be always selected as the first imaging option when possible.

Indications

In the pediatric population with CHD, CCTA is needed when echocardiography is incomplete or suboptimal and more anatomical details are needed for a definite diagnosis, or when extracardiac anatomical details are needed for clinical management of the patient and cardiac care. More specifically, several indications are recognized in pediatric population [1].

Coronary arteries

In patients with suspected abnormal origin of a coronary artery, CCTA has demonstrated good performances [50—52].

CCTA provides good visualization of coronary ostia, coronary dominance, angulation from the aortic root, ostium narrowing, and length of intra mural course and presence of coronary fistulas. In newborns and infants, the use of CCTA is limited because transthoracic echocardiogram (TTE) can accurately diagnose abnormal origin of a coronary artery in the majority of patients. CCTA could be complementary to TTE in patients with anomalous origin of the left coronary artery from pulmonary artery (ALCAPA) and anomalous origin of right coronary artery from pulmonary artery (ARCAPA). Symptoms of anomalous origin of coronary artery from opposite sinus of Valsalva (ACAOS) occur later in life, usually after infancy. The main indications to perform a CCTA to visualize coronary arteries in newborns are large coronary fistulas, absence of one coronary branch, postsurgical coronary complications (as in post-switch intervention), or unusual forms of anomalous origin of coronary artery. Furthermore, CCTA is useful in follow up of patients with Kawasaki disease, coronary aneurisms, or after surgery to check distal coronary branches or surgical sutures, avoiding repeated invasive angiography.

Aortic coarctation

In patients with complex aortic coarctation, CCTA provide important anatomical details not shown by echocardiography, especially for distal lesions. CCTA can be performed at the time of the diagnosis as a complement of TTE and during follow up after surgical correction or catheter intervention when complications such as restenosis, residual stenosis, aneurysm or pseudoaneurysm should be specified. After endovascular treatment, CCTA is suited to evaluate stent patency [53]. For patients suspected to have aortic arch hypoplasia, CT provides information about the exact location, shape and length of the hypoplastic segment as well as the course of the collateral vessels.

Complex arch anomalies

Aortic arch anomalies account 0.5 to 3% of CHD [54]. In the majority of complex arch anomalies, CCTA is mandatory to diagnose the type of anomaly and the relationship between the trachea and esophagus, which are surrounded by vascular structures. Eventual anomaly or compression of respiratory tree can also be identified.

Supra-valvular aortic stenosis

In focal or diffuse narrowing of the aorta starting at the sinotubular junction and often involving the entire ascending aorta, CCTA allows visualization of the entire aorta and is a reliable modality to demonstrate the extent of the supra valvular aortic stenosis. CCTA is able to determine the permeability of the coronary ostia, especially in Williams' syndrome, avoiding the risk of invasive coronarography. With ECG-gated technique, myocardial hypertrophy and the bicuspid valve could be depicted.

Aorto-pulmonary window

Aorto-pulmonary window is a communication between the ascending aorta and the pulmonary trunk or right pulmonary artery. It represents less than 0.1% of all CHD. Non-invasive evaluation with TTE may not demonstrate the communication in up to 37% of examinations [55]. CCTA demonstrates the communication between the aorta and the pulmonary artery as well as signs of pulmonary hypertension. It could precisely characterize the size, exact location of the defect, and the relationship with the coronary arteries origin. In this way, CCTA can play an important role and significant help to plan the surgical strategy.

Pulmonary vessels and major aorto-pulmonary collateral arteries (MAPCAS)

In all forms of pulmonary obstruction with suspicion of distal anomalies of the pulmonary arteries associated or not to the presence of MAPCAS, CCTA may define the distal anatomy of pulmonary branches and characterize the precise anatomy of MAPCAS. Invasive angiography is still performed in conjunction with CCTA to define the relationship between MAPCAS and native pulmonary branches and their eventual communication. CCTA corroborates invasive data and completes them with important anatomical details. 3D reconstructions of vessels and trachea permit understanding of their reciprocal relationship, allowing the surgeon to plan the surgical strategy. In patients with other complex anomalies, such as retro-trachea pulmonary artery (pulmonary artery sling, absent left pulmonary artery), CT may allow for precise detailing of distal anatomy and associated airway anomalies [56].

Pulmonary venous anomalies

In complex anomalies of pulmonary veins such as sub-diaphragmatic, mixed total anomalous pulmonary venous return, or scimitar syndrome, CT visualizes the precise anatomy of all pulmonary vein connections. CCTA should be performed when TTE is insufficient to diagnose a total anomalous pulmonary drainage in the coronary sinus or superior vena cava/innominate. When the anomalous drainage is sub-diaphragmatic or mixed type and the clinical status of the patient is not critical, CCTA is important to define the complete anatomy of pulmonary veins.

Transposition of great arteries

Patients with transposition of great arteries who undergo arterial switch operations at birth are at risk for coronary artery complications in late follow-up [57—60]. After arterial switch operations, patients aged 5—6 years benefit from coronary CCTA to analyze the coronary ostia and the proximal part of coronary arteries. Coronary artery complications after arterial switch operations usually concern the ostium and proximal part of the vessel. The position of the reimplantation of coronary ostia is also important to define the risk of late complication [60,61].

Intracardiac anatomy in complex congenital heart disease

In some patients with complex CHD when TTE is lacking concerning intracardiac details, CCTA is performed to define the relationship between great vessels and interventricular septal defects for surgical strategy. 3D modeling from CCTA data may be reconstructed and eventually printed to help in planning surgical strategy [62].

Conclusion

Cardiac CT is largely used in pediatric patients with CHD. Technological advances have improved spatial and temporal resolution of CCTA and speed of data acquisition and a concomitant decrease in radiation dose. However, in newborns and infants, CCTA should be performed as a second choice after echocardiography, only if strictly required with the benefit/risk balance kept in mind. In adolescents with CHD, cardiac MRI remains the first-choice imaging modality (except for in comprehensive studies of the coronary arteries), especially to avoid repeated radiation exposure during follow up. In patients with specific contraindications, ECG-CCTA can replace cardiac MRI and should be reserved for situations in which it is expected to provide important diagnostic information and less risk than other modalities.

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Disclosure of interest

The authors declare that they have no competing interest.

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