Pediatric Computed Tomographic Angiography: Imaging the Cardiovascular System Gently

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- Pediatrics • Cardiovascular disease
- Computed tomographic angiography
- Multidetector-row computed tomography
- Ultra-low dose radiation exposure

Cardiac and vascular disease in pediatric patients encompasses a broad spectrum of pathology. The majority of this pathology is congenital, resulting in alterations in gross and histologic structural morphology. Acquired pathology, however, is not uncommon; etiologies are often related to underlying systemic disease; surgical, endovascular, or procedural interventions; and blunt and penetrating trauma. Whether congenital or acquired, timely recognition and management of disease is imperative, as hemodynamic alterations in blood flow, tissue perfusion, and cellular oxygenation can have profound effects on organ function, growth and development, and quality of life for the pediatric patient.

Cardiovascular imaging plays a central role in diagnosis, treatment planning, and surveillance in this patient population. Non-invasive options include radiography, echocardiography, vascular ultrasound, magnetic resonance imaging (MRI) and angiography (MRA), computed tomographic angiography (CTA), single photon emission computed tomography (SPECT), and positron emission tomography (PET) CTA. Invasive catheter angiography (CA) remains the standard reference for all diagnostic modalities.

In considering which modality to use, it is important for the well being of the pediatric patient, to base decisions upon the benefits and risks of the examination. In general, non-invasive imaging is employed prior to invasive techniques, with selective use of the radiation modalities. Committing to a policy of safety first, leads to several salient questions regarding the application of state of the art computed tomography (CT) in assessment of pediatric cardiovascular disease, particularly in

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light of the advancements in cardiovascular MRI and MRA: What is the role of CTA in evaluating pediatric cardiovascular disease? Which patients are suitable candidates and what are appropriate indications for these patients? What radiation dose reduction strategies are available to achieve low radiation exposure while maintaining high diagnostic image quality?

The answers to these questions center on technology and imaging technique. Ensuring safe CTA practice and "gentle" as low as reasonably achievable (ALARA) pediatric imaging requires the cardiovascular imager to have strong working knowledge of CTA technical principles and clinical utilization balanced with sound understanding of pediatric cardiovascular anatomy, pathology, and pathophysiology. From this vantage point, CTA can be a useful adjunct along with the other modalities.

To assist the reader attain success in these endeavors, this review article presents a summary of dose reduction methodologies available to achieve 1–3 mSv low dose and submillisievert ultra-low dose radiation exposures in pediatric CTA (**Fig. 1**). Discussion points and recommendations are based upon 1550 consecutive exams performed over 39 months directly by or under the supervision of the lead author at the Children's Hospital of Philadelphia using a single source 64-channel Sensation multidetector-row computed tomography (MDCT) scanner (Siemens Medical Solutions, Malvern, PA, USA).[1] In the first portion of this review, CTA technical principles are discussed with an emphasis on dose reduction methodologies and safe contrast medium delivery strategies. Recommended parameters for currently available MDCT scanners are summarized in vendor-defined tables, while recommended radiation and contrast medium parameters are summarized in respective weight-based tables. In the second part of this work, an overview of pediatric CTA clinical applications is presented, illustrating low-dose and ultra-low dose techniques.

IMAGING OPTIONS: COMPLEMENTARY MODALITIES

Chest radiography is a valuable modality in the initial investigation of suspected congenital heart disease. Assessment of visceral—atrial situs, systemic veins, cardiac apex and chamber size, aortic arch sidedness and contour, pulmonary vascularity, and the axial skeleton readily can direct the working diagnosis, initial management, and further work-up. Recognition of the position and course of support devices can also aid in this process. Radiography provides similar useful information when investigating the peripheral vascular system, guiding early treatment and subsequent advanced imaging. When more detailed imaging is required, first-line considerations are echocardiography (heart, coronary arteries, pulmonary vasculature, thoracic aorta, intra-thoracic systemic veins) and vascular ultrasound (peripheral vascular system). Both afford non-invasive assessments of morphology, function, and flow without radiation or potentially nephrotoxic or allergenic contrast medium. From a workflow perspective, they are widely available, can be performed rapidly at the bedside or in the outpatient setting, and have low cost. With current technology and algorithms, real-time two dimensional (2D) gray scale and color Doppler images, spectral tracings, and CINE-loops are acquired

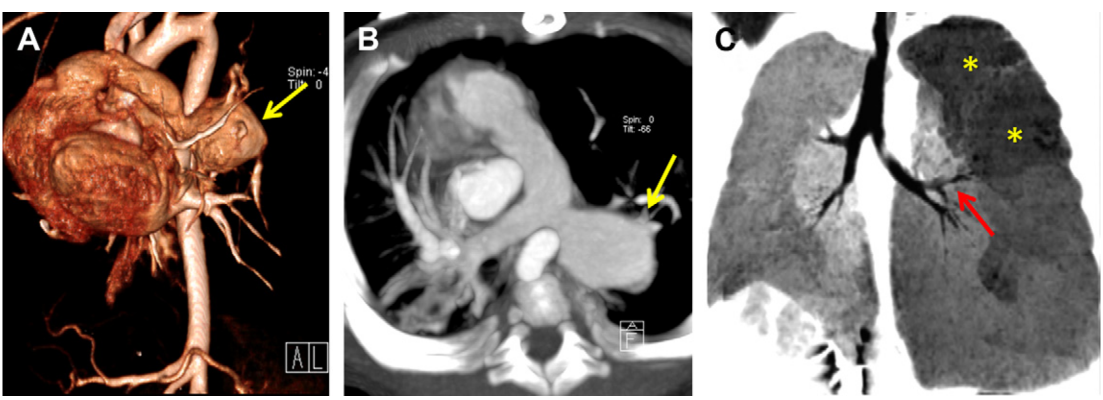

Fig. 1. A 3-month-old patient with increasing respiratory distress and a history of tetralogy of Fallot, absent pulmonary valve, and left pulmonary artery aneurysm (post plication). (*A*) Left anterior oblique volume-rendered (VR) image and (*B*) maximum intensity projection (MIP) axial image demonstrate a residual, large left pulmonary artery aneurysm (*yellow arrows*). (*C*) Minimum intensity projection (MinIP) image reveals hyperexpansion and air trapping in the left upper lobe (*asterisk*) secondary to aneurysm compression on the left upper lobe bronchus (*red arrow*).