



EDITORIAL COMMENT

New-generation multidetector computed tomography technology for the management of congenital heart disease in children: Now we can!



Avanços tecnológicos da tomografia computadorizada multicorte e sua aplicação no manejo das cardiopatias congénitas em idade pediátrica: agora podemos!

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During the last decade there have been marked improvements in computed tomography (CT) scanner technology. The first clinical CT scanners had limited use for cardiac applications, mainly due to poor spatial and temporal resolution, and also because of long scan times.¹ Current-generation multidetector CT (MDCT) scanners are characterized by rapid coverage of large anatomic volumes, with high spatial and temporal resolution and lower radiation doses.^{1,2} These recent developments have noticeably widened the cardiac applications of CT and made it an important tool in the assessment of congenital heart disease (CHD) in children.³

CHD is the most commonly occurring type of congenital anomaly, affecting 8-10/1000 live births.^{1,4} These are complex and challenging patients who often have residual hemodynamic lesions requiring repeated interventions throughout life, and therefore require close surveillance. Transthoracic echocardiography (TTE) is well established as the first-line imaging technique for assessment of CHD, due to its non-invasive nature and ability to detail cardiac morphology and function, and is both portable and widely available.^{1,5} However, TTE is operator-dependent, has a limited acoustic window and has several limitations in the visualization of complex anomalies involving extracar-

diac structures, particularly the coronary arteries and great vessels.⁵ As patients with CHD have a wide spectrum of morphologic variations, detailed and accurate information regarding the anatomy involved is crucial for preoperative planning. Advanced imaging techniques such as magnetic resonance imaging (MRI) and cardiac computed tomography angiography (CCTA) are therefore being more widely used as complementary techniques to TTE, in a multimodality imaging approach.^{1,6}

Cardiac MRI enables functional as well as morphologic assessment of complex CHD, and has multiplanar capability with a wide field of view, and no requirement for ionizing radiation. Compared with MRI, CCTA has the advantages of its ability to visualize intracardiac and extracardiac structures (including the airways and lung parenchyma), higher spatial resolution and much shorter scanning times (5-10 minutes), and for these reasons requires less sedation.⁵

Newer-generation dual-source CT scanners offer the advantage of submillimeter isotropic spatial resolution, and data acquisition requires only a part of the cardiac cycle or at most a few cardiac cycles. Prospectively ECG-triggered high-pitch scan mode or volumetric target mode provide full anatomic coverage of a pediatric thorax in less than a second or a single heartbeat, reducing both respiratory and cardiac motion. The higher spatial and temporal resolution combined with rapid image acquisition provide images of small cardiovascular structures, like coronary arteries, con-

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duits, baffles, and the anatomy of the thoracic arterial and venous vasculature with high diagnostic accuracy, even at high heart rates. This rapid image acquisition also reduces or eliminates the need for sedation or anesthesia in small children who are unable to cooperate with a short breath hold, while still providing good image quality.^{1,6,7} On top of this, the prospectively ECG-triggered high-pitch spiral mode provided by second-generation dual-source CT technology, with a high pitch of 3.4 and fast table speed of 460 mm/s, can substantially decrease radiation doses because of its fast, non-overlapping spiral data acquisition. Recent studies have shown that prospectively ECG-triggered high-pitch mode is feasible in children with CHD.⁷ This is of paramount importance because, despite these strengths, ionizing radiation exposure associated with CCTA is still one of the main limitations of the use of this technique at pediatric ages.^{5,7}

All imaging modalities that use radiation must adhere to the 'as low as reasonably achievable' (ALARA) concept regarding the radiation dose delivered by the exam. This principle is even more important in the pediatric population. It is generally acknowledged that radiation dose is more concerning for a pediatric than an adult patient due to a relative increase in radiation sensitivity and a longer life span during which adverse effects may manifest clinically.⁶ Moreover, there are concerns about the number of imaging examinations that a child with CHD will undergo throughout life, due to the risk of radiation-induced chromosome damage caused by cumulative radiation, with increased lifetime risk of malignancy.^{3,5,7}

Considerable efforts have therefore been made to develop CT technology in order to substantially reduce radiation exposure.³ Several dose-saving strategies are in routine clinical use in pediatric CT, especially for neonates and young children, including body size-adaptive CT protocols, reduced tube voltage, tube current modulation and prospective ECG triggering as mentioned above.⁵ If other factors are kept constant, decreasing the tube voltage from 120 to 80 kVp can by itself result in up to 65% dose reduction.⁶ In infants and children, tube potential should be reduced to 70 or 80 kVp when performing cardiac CT. Many teenagers and young adults can be imaged with 80 kVp as well, reserving 100 kVp for muscular or mild to moderately overweight patients.^{6,8} Automatic tube current modulation selects the lowest possible tube current (mAs) for a given tube potential (kV), maintaining fairly constant image noise throughout the exam by varying mAs based on tissue attenuation. This software can reduce radiation doses by up to 40-50% over standardized imaging algorithms.⁶ However, these aggressive radiation dose reduction protocols could lead to degraded image quality due to higher susceptibility to beam-hardening artifacts and increased image noise because of low photon flux. The use of advanced iterative reconstruction techniques results in improved image quality, primarily by reducing image noise, and allows further dose reduction without compromising diagnostic image accuracy.⁷

In their article published in the current issue of the *Journal*,⁹ Öztürk and colleagues explore recent advances in CT technology and how these have widened the cardiac applications of CT, highlighting the role of latest-generation MDCT scanners as another tool for the assessment of CHD in pediatric patients. CCTA exams were performed with a

320-row MDCT scanner, and a low radiation dose protocol was used. Tube current was adjusted to the patient's weight and a tube voltage of 80 kV was used for patients weighing less than 20 kg. The same tube voltage could have been used with patients up to 50-60 kg, further lowering the radiation exposure in these cases.⁶ The authors conclude that intracardiac malformations and cardiovascular connection anomalies were more accurately determined by TTE than by CCTA, while there was no significant difference between these two techniques in predicting great vessel malformations. This latter finding is not consistent with other studies in the literature that found MDCT angiography to be more effective than TTE in visualizing extracardiac vascular structures.^{3,10-12} The authors performed CT scans without ECG gating, which may partially explain these findings. Prospectively ECG-triggered scan mode improves image quality and diagnostic accuracy, and allows lower radiation exposure. Although decreasing the tube voltage and tube current can effectively reduce the dose of radiation received by the patient, the level of radiation exposure in children can remain high in the absence of prospective ECG gating. The authors also highlight the importance of the experience and knowledge required to perform high-quality CT scans in pediatric patients with CHD. The imaging physician needs to be actively involved in directing patient preparation and establishing the image acquisition protocol, which has to be tailored to the individualized patient. The interpretation and reporting of CHD CT scans is time-consuming and demands expertise that combines the skills and knowledge of both radiology and pediatric cardiology.

In the current era, a non-invasive multimodality imaging approach to the patient with CHD is crucial to better planning of invasive procedures. With the advent of new-generation scanners using fast sequences with higher spatial and temporal resolution and aggressive radiation dose reduction techniques, allowing scan radiation doses lower than 1 mSv and maintaining diagnostic image accuracy, cardiovascular CT is increasingly being used in the pediatric population as an adjunct to echocardiography when cardiac MRI is considered high risk, contraindicated, or unlikely to provide the answer to the clinical question.

So, now we can ... apply the latest CT technology to selected pediatric CHD patients, in order to improve their clinical management and outcomes.

Conflicts of interest

The author has no conflicts of interest to declare.

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