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Editorial

# The challenge of imaging congenital heart disease in neonates: How to minimize radiation exposure with advanced CT technology

Imaging plays a key role for diagnosis and further treatment planning of congenital heart disease (CHD). While echocardiography is the primary tool in the initial diagnostic triage, multimodality imaging is increasingly being used for improved accuracy of the primary congenital diagnosis while the detection of incidental findings in complex disease can be essential for surgical planning.

Ventricular septal defects (VSD) are one of the most common malformations in children < 1 year of age, and commonly found in association with conotruncal anomalies (i.e., transposition of the great arteries, tetralogy of Fallot, truncus arteriosus), and hypoplastic heart syndrome. Isolated VSDs are one of the most common congenital defects in children < 1 year old and occur in approximately 78% of malformations.[1] Depending on the size and location in the septum and interventricular flow dynamics, isolated VSDs may close spontaneously after birth, or persist and cause severe left-to-right shunting requiring early surgical correction. VSD size is of most importance in the clinical management and can be classified into small, moderate and large defects using the absolute diameter *(small <* 10 mm*, moderate 10*–15 mm*, large >* 15 mm*)*, or the relative size referenced to the aortic annulus *(small < 0.33, moderate 0.34–0.66, large > 0.66)*. When it comes to heart surgery, exact knowledge of the location of the defect is of utmost importance, especially in complex CHD where patency or even enlargement of VSD may become part of the corrective strategy (Rastelli – type correction). In most neonatal cases echocardiography allows for accurate classification of defect type and hemodynamic impact but with evolving surgical techniques, like hybrid or transcatheter settings, an "enlarged" view of cardiac defects and adjacent structures is required in the planning of cardiac surgery.

Although an isolated VSD is the most common cardiac anomaly in children, additional congenital anomalies can go undetected when only a single imaging modality is used to evaluate patients as evident in the study by Nau,[2] which identified 55 additional cardiac malformations, and 62 additional vascular anomalies.

Cardiac MRI is an excellent imaging modality for congenital heart disease to identify both structural and functional anomalies using a combination of cine' and flow imaging techniques. However, cardiac MRI can be a challenge in pediatric patients with any amount of complexity. Examination times can be long (up to 1 hour), sedation may be required, and critically ill newborns may need multiple intravenous lines.

In contrast, a cardiac CT exam may only take a few minutes of setup, and the imaging time is short. For example, an ultrafast scan may take only 0.3 sec using a high-pitch CT factor of 3.4.

Neonates often weigh only 3 kg or less (> 1.5 kg) and because MRI has a lower spatial resolution (1.0 mm vs 0.5–0.65 mm) compared with cardiac CT, small structures such as the coronary arteries are impossible to visualize by MRI.

In the present study by Nau et al.[2] the accuracy of dual source computed tomography angiography (CTA) is compared to intraoperative findings and echocardiography. Out of 154 patients that underwent dual-source CTA of the chest using a high-pitch protocol at low tube voltages (70–80 kV), 55 underwent surgical repair of a VSD (median age 8 days, range 1–348 days). The margins of the VSDs and their relation to the surrounding structures were reproduced by en-face multiplanar reformations (MPR). Absolute diameter, normalized area and relative area compared to the aortic valve annulus were used for discrimination between restrictive and non-restrictive defects.

Dual source CT was found to be more accurate than echocardiography, as compared to intraoperative findings, terms of VSD sizing, and for defining location and orientation. CT correctly classified the type of VSD in 96.4%, whilst the accuracy of echocardiography was only 87.3%, compared to the intraoperative reference standard. Furthermore, echocardiography systematically underestimated the effective VSD size. These findings are important because cardiac CT is an underutilized modality in children predominately due to the practice patterns of pediatric cardiologists and concern about radiation dose.

The median radiation dose in the study by Nau et al.[2] was very low with **0.32 mSv (range 0.12–2.00 mSv)** 128 –slice for dual source CT angiography, which, in comparison to conventional catheterized diagnostic coronary angiography, is significantly lower.[3] Overall, standardized benchmark reporting in pediatric fluoroscopy has shown high variations in radiation exposure due to different benchmarks.[4]

Furthermore, the 3rd generation dual source CT has a novel detector material, which maintains highest image quality while lowering radiation exposure by allowing for lower tube current mAs settings. Radiation dose was even lower for the new 3rd generation 128-slice dual source CT model, with 0.22 mSv, as compared to 2nd generation scanner, introduced in 2010, with 0.44 mSv.

Radiation dose savings by CTA can be achieved by multiple technical strategies: 1) iterative image reconstruction[5] 2) low tube kilovoltage (kV) setting of 70kV-80 kVp 3) optimization of mAs to the individual body dimensions (BMI) using either customized tables or automated tools 4) a high–pitch (up to 3.4) factor using dual source CT technology with ECG-synchronization, enabling "single-beat" capturing of the heart, defined as CT image acquisition within one cardiac cycle, and even during breathing, without motion artifacts.[6]

It should be kept in mind that first, a pediatric CT scan is a complex procedure that must be tailored to the specific indication and scanner type, while two landmark societal guidelines give a good "outline" on how to manage pediatric patients.[7,8]

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Because of the spectrum of complexity and random nature of congenital heart disease, it is difficult to perform randomized controlled studies comparing diagnostic modalities. This retrospective analysis by Nau et al.[2] is an important beginning of the scientific study of cardiac CT for the assessment of ventricular septal defects. This work will ideally spawn more research into the use of cardiac CT for more complex congenital heart disease.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcct.2019.03.009.

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