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Contrast medium application in pediatric high-pitch cardiovascular CT angiography: Manual or power injection?

Marc Saake MD[a,*], *Michael M. Lell MD*[a], *Oliver Rompel MD*[a], *Martin Gloeckler MD*[b], *Matthias May MD*[a], *Achim Eller MD*[a], *Stephan Achenbach MD*[c], *Michael Uder MD*[a], *Wolfgang Wuest MD*[a]

[a] *Department of Radiology, University of Erlangen-Nuremberg, Maximiliansplatz 1, Erlangen 91054, Germany*
[b] *Department of Pediatric Cardiology, University of Erlangen-Nuremberg, Erlangen, Germany*
[c] *Department of Cardiology, University of Erlangen-Nuremberg, Erlangen, Germany*

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ABSTRACT

Background: Dual-source CT offers accurate depiction of cardiac structures in children with congenital heart disease. For cardiac CT, optimal enhancement of the cardiovascular structures is essential. There is considerable controversy about the administration of contrast medium (CM) in infants and small children, with either a power injector or a manual (hand) injection.
Objective: The aim of this study was to compare image quality with power injection of CM (study group) and manual injection (control group).
Methods: Thirty-four patients (study group, 6.8 ± 9.6 months and control group, 4.6 ± 8.9 months, nonrandomized) underwent dual-source CT angiography of the chest using a prospective electrocardiography-triggered high-pitch spiral mode (pitch, 3.4; 80 kV). In the study group (17 patients), a power injector was used, and in the control group (17 patients, historical group), manual CM injection had been performed. To assess image quality, both subjective and objective parameters were evaluated independently by 2 experienced radiologists.
Results: Subjective overall image quality, signal-to-noise ratio, and contrast-to-noise ratio were significantly higher using power injection compared with manual injection ($P < .05$). However, depiction of cardiovascular structures did not differ significantly between both groups in all evaluated regions except the superior vena cava and the coronary arteries.
Conclusion: In infants and small children with congenital heart disease, both manual and power injector protocols allowed for diagnostic imaging of cardiac and extracardiac structures. However, image quality and vascular attenuation were superior using a power injector.

Conflicts of interest: M.M.L. is currently receiving honoraria from Bayer and Siemens Germany. M.M. is on the speaker's bureau for Siemens Germany. M.U. is on the speaker's bureau for Bayer, Bracco, and Siemens Germany. W.W. is on the speaker's bureau for Siemens Germany. M.S., O.R., M.G., A.E., and S.A. declared none.

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* Corresponding author.
E-mail address: marc.saake@uk-erlangen.de (M. Saake).

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1. Introduction

Congenital heart disease (CHD) is a common condition with an estimated incidence of up to 10 in 1000 live births. Because of decreased mortality and better long-term survival, nowadays, approximately 90% of all patients with CHD reach adulthood.[1] Nonetheless, these patients have to cope with repetitive therapeutic and palliative procedures in their lifetime.

For the evaluation of CHD, the accurate depiction of complex cardiac structures both before and after surgery is mandatory. Different imaging techniques are used to assess CHD: echocardiography, diagnostic cardiac catheterization, CT, and magnetic resonance imaging (MRI).

Echocardiography remains the mainstay for noninvasive imaging of CHD and, in the hand of experienced specialists, renders sufficient information for diagnosis and therapy planning in most patients. However, in delineating extra-anatomic bypasses or systemic shunts, echocardiography is limited. In these cases, CT and MRI provide complementary information on vascular and extracardiac abnormalities. Generally, cardiac MRI provides high-quality images and more accurate morphologic analyses than echocardiography[2] but suffers from limitations of inferior spatial resolution, artifacts from implanted metal, higher cost, limited availability, contraindication in imaging of patients with pacemakers, and the need for intubation and mechanical ventilation.[3–7] Especially in critically ill neonates, MRI may not be feasible. CT has the drawback of ionizing radiation and the application of iodinated contrast medium (CM) compared with echocardiography and cardiac MRI. Yet, it is able to visualize complex cardiovascular anatomic features and pulmonary arterial and venous structures with a high temporal and contrast resolution. Dual-source CT, which permits prospective electrocardiography (ECG)-triggered high-pitch spiral acquisition, is a potential diagnostic alternative in children with CHD without excessive radiation exposure or CM application.[8,9] For cardiac CT, optimal enhancement of the cardiovascular structures is essential. Typically, pediatric CT scans are performed at low kilovoltages (ie, 80 kV) to improve contrast-to-noise ratios (CNRs) and reduce radiation dose.[10,11] Several factors influence the enhancement, including the type, volume, flow rate, route, and method of CM administration.[6] In infants and small children with suspected CHD, the use of small-gage intravenous lines, small volumes of CM, unusual circulation, and vascular access sites make optimal visualization of all cardiac and extracardiac structures difficult.[6] There is considerable controversy about the administration route of CM, with either a power injection or a manual (hand) injection.

The aim of this study was to compare the image quality with manual injection of CM and power injection using an ECG-triggered high-pitch spiral acquisition in a cohort of pediatric patients with CHD.

2. Methods

2.1. Study population

Seventeen patients (11 boys and 6 girls; mean age, 6.8 ± 9.6 months; range, 0–35 months; body weight, 5.7 ± 2.9 kg; range, 3–13 kg) who underwent cardiac CT as part of the diagnostic workup before surgery between May and October 2013 were included in the study group. Inclusion criteria were known CHD and age <3 years. Exclusion criteria were known CM intolerance, acute renal failure, or an incomplete examination. All patients of the study group had power injection of CM.

An age-matched historical control group of 17 patients (12 boys and 5 girls; mean age, 4.6 ± 8.9 months; age range, 0–28 months; body weight, 4.7 ± 2.8 kg; body weight range, 2–13 kg) who underwent cardiac CT in our department with the same scan protocol but with manual CM injection was retrieved from our picture archiving and communication system (PACS).

In all patients, the parents or their legal guardians gave written informed consent. The study was approved by the institutional review board.

2.2. Cardiac CT

All scans were performed with prospective ECG-triggered dual-source CT (SOMATOM Definition Flash; Siemens Healthcare, Forchheim, Germany) with the following parameters: 0.28 seconds gantry rotation time, 2 × 128 × 0.6 mm slice acquisition using a z-flying focal spot, real-time, anatomy-based tube current modulation (CareDose4D, 400 mAs reference dose; Siemens Healthcare, Forchheim, Germany) at 80-kV tube voltage and 450 mm/s table speed (pitch, 3.4). Infants were secured in a commercially available support cushion and fixed with broad Velcro strips on the CT table. From the raw data set, images with 0.6-mm slice thickness for multiplanar reformat and axial and coronal images with 2-mm slice thickness and 2-mm increment were reconstructed using filtered back projection with a standard (B26f) and a high-resolution (B70f) kernel. Subsequently, the image data sets were transferred to a three-dimensional workstation (SyngoVia; Siemens Healthcare) for further evaluation.

CM (ULTRAVIST; Bayer Healthcare, Leverkusen, Germany) was injected preferably in a right antecubital vein (22-gage intravenous catheter); otherwise, a cephalic intravenous site was used. If necessary, patients received mild intravenous sedation with midazolam.

In the study group, a power injector (Medrad Stellant CT; Bayer, Leverkusen, Germany) was used for contrast application. A mixture of 50% saline and CM, equivalent to 150 mg iodine/mL, preheated to body temperature was injected. To keep scan delay comparable with manual injection, the bolus length was set empirically to 12 to 14 seconds. The amount of CM resulted from the body weight (2 mL CM/kg body weight [300 mg/mL], corresponding to 4 mL of diluted CM/kg body weight [150 mg/mL]). The flow rate was calculated by dividing the amount of CM through the bolus length (eg, 6 kg body weight, 24 mL/12 seconds = 2 mL/s). The scan was started immediately after the CM injection was finished without further delay. The CM bolus was followed by a saline bolus of 10 mL. Table acceleration required 1 to 2 seconds. During this period and the scan itself, the saline bolus was running.

For manual injection, the amount of CM was adapted to the body weight (2 mL CM/kg body weight [300 mg/mL]). To reduce viscosity, 5 parts of CM were diluted with 1 part of saline,