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Feasibility of high-pitch spiral dual-source CT angiography in children with complex congenital heart disease compared to retrospective-gated spiral acquisition

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AIM: To investigate the use of second-generation dual-source high-pitch computed tomography in obtaining confident diagnostic image quality using a low radiation dose in young patients with congenital heart disease (CHD).

MATERIALS AND METHODS: From July 2014 to June 2016, 50 consecutive children $<$4 years with complex CHD underwent electrocardiography (ECG)-triggered dual-source computed tomography (CT). The patients were assigned randomly to two groups: high-pitch (pitch 3.4) spiral dual-source CT acquisition (group A) and retrospectively spiral dual-source CT acquisition (group B). The image quality, diagnostic accuracy, coronary artery origin, course demonstration, and radiation exposure were compared between the two groups.

RESULTS: Fifty examinations were performed (group A, 25; group B, 25). There were no significant differences in image quality, diagnostic accuracy, coronary artery origin, and course demonstration between the two groups. The image quality scores were 1.3$\pm$0.4 in group A and 1.1$\pm$0.3 in group B (p=0.2). The diagnostic accuracy was 100% in both groups. The coronary arteries were traceable in 80% in group A and 84% in group B (p=0.7). A single coronary artery was identified in one case in group A and the left anterior descending (LAD) branch originated from the right coronary artery (RCA) in one case in group B. There were significant differences in the effective doses between the two groups (0.40$\pm$0.20 mSv in group A and 2.7$\pm$1.0 mSv in group B, $p<0.05$).

CONCLUSION: Intra-cardiac and extra-cardiac malformation, coronary artery origin, and course malformation can be visualised clearly using a high-pitch ECG-triggered dual-source CT with a low radiation dose and good image quality in patients with CHD.

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Introduction

Congenital heart disease (CHD) is a malformation of the heart that mainly occurs in infants. Each year, about 10 million babies are born in China, of which 0.8% suffer from CHD. Therefore, accurate diagnosis can help select

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appropriate therapeutic strategies and to improve their prognosis.

Ultrasound is the most common diagnostic tool for children with CHD as it is convenient, cheap, and free of radiation; however, it is limited regarding the demonstration of extra-cardiac malformations and strongly dependent on the operator. Magnetic resonance imaging (MRI) is suitable to demonstrate extra- and intra-cardiac malformations and accurately measures cardiac function and flow, but it is time-consuming and noisy, and in young children, MRI almost invariably requires a general anaesthetic, which hinders its extensive application. The use of multi-detector computed tomography (MDCT) in children is limited due to its high radiation dose;[1,2] however, with the development of new techniques, flash speed and low doses can be achieved using second-generation dual-source computed tomography (DSCT) (Definition Flash; Siemens Healthcare, Forchheim Germany), which is equipped with 128 section-acquisition detectors providing a high-pitch spiral mode. In this scan mode, the entire volumetric data acquisition can be completed within one cardiac circle with a high pitch of 3.4 and a fast table speed of 460 mm/s.[3,4] This may obviate the need for general anaesthesia, which is almost always necessary in MRI for children under the age of 5–6 years. The present study sought to determine whether a low dose can be achieved using the prospectively electrocardiography (ECG)-triggered high-pitch DSCT for good image quality in children with CHD.

Materials and methods

Patients

The study was approved by the institutional Ethical Committee and informed consent was obtained from the parents of each patient. From July 2014 through June 2016, consecutive infants and children <4 years with complex CHD underwent ECG-triggered DSCT during free breathing. The patients were randomly assigned into two groups: high-pitch (pitch 3.4) prospectively spiral DSCT acquisition (group A) and retrospectively spiral DSCT acquisition (group B). All potential adverse effects of contrast media injection and radiation exposure were explained to patients' legal guardians.

CT angiography protocol

All the children underwent CT angiography on a second-generation DSCT system (SOMATOM Definition Flash; Siemens Healthcare). During the CT examination, all the patients were sedated using oral administration of chloral hydrate under the supervision of a paediatrician and were breathing quietly. All the scans were performed using electrocardiographic gating. The scanning field was from the thoracic inlet to the liver bottom. Group A scans were obtained at a scan pitch of 3.4. Data acquisition was prospectively ECG triggered, starting at 30% of the R–R interval. The imaging parameters were as follows: a section configuration of 128×0.6 mm, a gantry rotation time of 280 ms, a tube voltage of 80 kV, and the tube current was adjusted with automatic modulation according to the patients' size and the anatomical region (CARE Dose 4D; Siemens Medical Systems). The acquisition time was <1 second. Group B scans were obtained using retrospectively spiral DSCT acquisition at a scan pitch of 0.2–0.3. The imaging parameters were the same as above. The tube current was adjusted with automatic modulation according to the patients' size and the anatomic region (CARE Dose 4D). An ECG-controlled tube current modulation was used for the ECG-gated scan. The full-dose acquisition was at 30–80% phases, with the low-dose (20% of full dose) acquisition at other phases. The acquisition time was <6 seconds. Each patient received 1.5 ml/kg iopromide (350 mg iodine/ml; Ultravist, Schering, Berlin, Germany) intravenously through the antecubital vein at a speed of 1 ml/s, followed by 10–20 ml saline at the same speed. A manual visual trigger was used to check the opacity of the chambers during the arterial phase of contrast medium injection for the initiation of imaging acquisition according to the region of clinical interest. Iterative reconstruction was used for image processing with sonogram-affirmed iterative reconstruction (SAFIRE; Siemens Healthcare) algorithm that used the corresponding "-I26f " kernel for groups A and B.

Image post-processing and data analysis

Axial image data were transferred to a computer workstation for post-processing (Circulation 2 workstation, Siemens, Forchheim, Germany). Full volumes were reformatted using volume rendering (VR), maximum-intensity projection (MIP), multiplanar reconstruction (MPR), and curved planar reconstruction (CPR). The images were reviewed by two experienced paediatric radiologists (with 8 and 5 years of experience in paediatric cardiac radiology). A four-point subjective scoring system was used (1, excellent; 2, good; 3, moderate; and 4, impaired/unacceptable). The scores were defined as follows: 1 (excellent), excellent image quality with clear definition of the cardiac and extra-cardiac anatomical structure; 2 (good), good image quality with well-maintained definition of the cardiac and extra-

Table 1
Patient demographics in groups A and B.

Demographics	Group A (n=25)	Group B (n=25)	p-Value
Number of boys	16 (64%)	14 (56%)	0.5
Age, (months) mean±SD	19.7±9.7	22.1±14.5	0.6
Weight, (kg) mean ±SD	10.0±3.3	9.5±3.0	0.7
Heat-beats during scan (beats/min)	108.6±20.5	109.6±19.5	0.9

Table 2
The objective image quality score in groups A and B.

	Group A	Group B	p-Value
Descending aorta Attenuation	377.2±123.3	438.4±136.1	0.08
Noise	22.7±11.1	21.4±11.1	0.7
Attenuation of muscle	71.1±23.9	67.7±16.7	0.5
SNR	21.2±14.9	26.6±19.5	0.2
CNR	21.2±14.9	22.4±18.2	0.8

SNR, signal-to-noise ratio; CNR, contrast-to-noise ratio.

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