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Prospective ECG-triggering cardiac CT for infants with complex congenital heart disease using low-dose contrast medium, low tube voltage, and adaptive statistical iterative reconstruction

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AIM: To demonstrate the clinical value of prospective electrocardiography (ECG)-triggered cardiac computed tomography (CT) with low concentration contrast medium, low tube voltage, and adaptive statistic iterative reconstruction (ASIR) to reduce both radiation and contrast dose in examining infants with complex congenital heart disease (CHD).

MATERIALS AND METHODS: Forty-four consecutive infants (19 male, 25 female, age: 8.06±4.33 months, weight: 7.31±1.36 kg) with complex CHD underwent prospective ECG-triggered low-dose cardiac CT using 80 kVp and 120 mA. The contrast agent was iodixanol (270 mg iodine/ml, Visipaque, GE Healthcare, Co. Cork, Ireland). Cardiac CT images were reconstructed with 70% ASIR. The quantitative CT image quality was assessed by image noise in adipose tissue and contrast-to-noise ratio (CNR) in the aorta. The qualitative image analysis was performed on a five-point grading scale by two independent reviewers and interobserver variability was calculated. The results of 32 CT examinations were also compared with the available surgical results for diagnostic accuracy evaluation.

RESULTS: The effective dose was 0.55±0.10 mSv for the patient population. The iodine load was 3.95±0.73 g iodine. Image noise in adipose tissue was 16.24±1.42 HU and CNR in aorta was 21.90±7.10. All images were acceptable for diagnosis with an average score of 4.52±0.38 and good agreement between reviewers (kappa=0.75). Compared to the surgery results in 32 cases, CT was 97% and 88% accurate diagnosing extracardiac and intracardiac defects, respectively.

CONCLUSION: Prospective ECG-triggered cardiac CT using 80 kVp, low-concentration iodinated contrast agent (270 mg iodine/ml) and 70% ASIR reconstruction provides excellent image quality and accurate diagnosis for complex congenital heart disease in infants with reduced contrast medium dose and low radiation dose.

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Introduction

Congenital heart disease (CHD) in infants is a difficult area of diagnostic radiology because of the small body size and fast heart rate. Computed tomography (CT) is increasingly applied to enable clinical decision making in infants with CHD, because of its excellent spatial resolution, adequate temporal resolution, and fast acquisition time; however, radiation dose exposure from CT is of particular concern due to the possible harmful effect. Compared to adults, infants and children are more sensitive to radiation and have a longer lifespan to develop potential radiation injuries.[1] Besides ionizing radiation, cardiovascular CT also involves the use of iodinated contrast agents, which are a potential source of nephrotoxic and cytotoxic effects. A recent study reported that the application of iodinated contrast agents during diagnostic radiography procedures led to a clear increase in the level of radiation-induced gene damage,[2] although there is no direct evidence that it could translate to an increase in malignancy. Despite the potential risks caused by radiation and contrast medium, CT is particularly useful for the assessment of cardiovascular anomalies, especially of airway abnormalities. Recently updated CT imaging techniques such as low tube voltage and low-concentration iodinated contrast agent with iterative reconstruction algorithms such as Adaptive Statistical Iterative Reconstruction (ASIR) for image reconstruction not only reduce the radiation and contrast doses, but also aid the interpretation of CT findings.[3–7] The purpose of the present study was to review the clinical values of the optimization of image acquisition protocols in cardiovascular CT with low-concentration iodinated contrast agent and low tube voltage prospective electrocardiography (ECG) triggering and ASIR for infants with complex CHD.

Material and methods

Study population

This is a Health Insurance Portability and Accountability Act of 1996 (HIPAA)-compliant prospective research study and was approved by the institutional review board. Written informed consent was obtained from the parents of all patients for clinical imaging. A total of 44 consecutive patients were enrolled in March 2016 for the study. The inclusion criteria were infants with CHD who were scheduled for cardiac CT for further information and their body weight was between 5–10 kg. The exclusion criteria were hypersensitivity to iodine contrast medium, impaired renal function defined as creatinine clearance <60 ml/min. No patient was excluded using the exclusion criteria during the patient collection period. There were 19 male and 25 female patients. The mean age and heart rate was 8.06±4.33 months (range, 2–19 months) and 115.61±14.15 beats/min (range, 85–141 beats/min), respectively, and the mean weight was 7.31±1.36 kg (range, 5.2–10 kg; Table 1).

Table 1
Clinical, image quality, iodine load, and radiation dose information in 44 cases.

Clinical information		5–10 kg
Gender	Male	19
	Female	25
Age (months; mean±SD)		8.06±4.33
Heart rate (beats/min; mean±SD)		115.61±14.15
Weight (kg; mean±SD)		7.31±1.36
Image noise (HU)		16.24±1.42
CNR		21.90±7.10
Iodine load (g iodine)		3.95±0.73
CTDIvol (mGy)		1.35
DLP (mGy·cm)		13.67±3.87
ED (mSv)		0.55±0.10

CT protocols

All 44 patients were scanned on a 64-section high-definition CT system (Discovery CT 750 HD, GE Healthcare, Waukesha, WI, USA) during free breathing with sedation and each patient underwent a prospective ECG-triggering paediatric cardiac CT examination. The prospective scanning sequence was as follows: step-and-shoot axial scanning and a collimation of 64×0.625 mm with a scan field of view of 25 cm and gantry rotation speed of 0.35 seconds; the matrix was 512 × 512. A tube voltage of 80 kV and tube current of 120 mA was used. The data acquisition window was 380 ms with padding technique. The centre of the data acquisition window was set at 35–45% of the R–R interval when the heart rate was >75 beats/min and at 65–85% of the R–R interval when heart rate was <75 beats/min. All Discovery CT750HD scanners are equipped with the ASIR algorithm. ASIR is a reconstruction technique that can reduce image noise and improve image quality by modelling noise in the projections compared with the traditional filtered back-projection (FBP) reconstruction algorithm. To restore the more classic appearance of CT images, a linear blend of the traditional FBP method with ASIR has been implemented on the scanner with the blending percentage from 0% to 100%, 0% corresponding to a conventional FBP image and 100% corresponding to a pure ASIR image.[3,8] In the present study, all scans were reconstructed using 70%ASIR algorithm.

The non-ionic contrast agent, iodixanol, (Visipaque, 270 mg iodine/ml concentration, GE Healthcare, Co. Cork, Ireland) at a volume of 1–1.5 ml/kg was injected through a peripheral vein using a dual-head power injector at an injection rate of 0.8–2 ml/s and followed by 5–10 ml saline at the same injection rate to reduce artefacts caused by undiluted intravascular contrast agent.

Quantitative analysis of image quality

The signal intensity (Hounsfield unit mean value) was measured at the aortic root and thymus with regions of interest (ROI) of 0.8–1.2 cm^2 by a single reader. The noise (standard deviation [SD] of signal intensity) was measured

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