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RESEARCH ARTICLE

CARDIAC CT ANGIOGRAPHY IN NEONATES WITH COMPLEX CONGINETAL HEART DISEASE: RADIATION DOSE OPTIMIZATION BY IMPLEMENTING LOW DOSE RADIATION PROTOCOLS

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ABSTRACT

Background: The use of CTA in patients with CHD has been limited by concerns about high radiation exposure. Recent-generation CT scanner technology significantly reduces radiation exposure compared with older technology. By implementing low dose radiation protocols, Case specific protocols, the radiation dose can be significantly reduced. Materials and Methods: The prospective study included 50 patients with complex congenital heart disease who received CT angiography. The examinations were performed as a high pitch CTA, with Contrast administration (1.5ml/kg body weight) and fixed scan delay. Radiation dose parameters were modified inorder to lower the effective radiation dose. Results: The median CT dose index volume ($CTDI_{vol}$) was 0.45 (range 0.14-0.95 mGy), the median dose-length product was 9 (range, 4-18 mGy*cm). The estimation of the effective dose by Monte carlo simulation revealed lower median dose levels 1.72 (range 0.99-2.88) $msv.mGy^{-1}.cm^{-1}$ Conclusion: Cardiac high-pitch CTA on neonates with CHD can be performed safely and dose reducing protocols can be implemented without compromising image quality.

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INTRODUCTION

Cardiac CT is important in the evaluation of Paediatric congenital heart disease (CHD). It can be used for accurate depiction of complex cardiovascular anatomic features both before and after surgery and of a variety of post treatment assessment of extra cardiac systemic and pulmonary arterial and venous structures [1,2].Children with congenital or acquired heart disease can be exposed to relatively high lifetime cumulative doses of ionization radiation including radiography, fluoroscopic procedures and nuclear cardiology imaging. Thus there is utmost importance of decreasing the radiation doses by optimizing CT protocols to overcome detrimental consequences[3]. The prospective study was conducted for period of two years. The objective of the study was to calculate average radiation dose to children during gated /non-gated CT angiography for Complex Congenital heart disease by implanting the low radiation dose protocols.

CT imaging Protocol: The cases of Complex Congenital heart disease diagnosed by echocardiography were subjected to Cardiac CTA in order to calculate average radiation dose. In most patients with CHD, non-ECG-Synchronized CT is sufficient, However in patients suspected for intra-cardiac or extra-cardiac shunts, coronary fistula's, ECG synchronized CT angiography is preferred to optimize image quality and to reduce motion artifacts.

All cases of Complex Congenital heart disease diagnosed by echocardiography were subsequently subjected to Cardiac CTA. All Cardiac CT studies are examined on 64slice CT: SOMATOM Sensation (Siemens Germany) The patients had kept 4hr fasting before examination, drinking of water or clear fluids up until time of examination is not restricted and is even encouraged to prevent contrast toxicity. As a first step, i.v cannulation is performed using 24 gauge cannula for age group <4years, and 22 guage cannula for age group >4yrs.Children who were <4 years old and uncooperative were orally administered 10% chloral hydrate, at a dose of 50 mg/kg, 30 min before MSCT scanning. Children aged 4 years or olderrespond satisfactorily to verbal reassurance. Non-ionic contrast agent (350 mg I/mL, total dose 2.0 mL/kg) was injected at 0.6–4.0 mL/s, based on the child's age, weight, and peripheral vascular conditions. Normal saline (same volume as the contrast agent) was then injected at the same rate.Low dose radiation protocols were employed to reduce radiation dose, low kvp, case dose protocol. The Method used is Real-time contrast bolus tracking. Region of interest is placed in the right side of heart for evaluation of pulmonary arteries and in the left side of heart for evaluation of the thoracic aorta. Diagnostic image acquisition begins at specific attenuation threshold, typically between 160HU. Field of view is from T1vertebral level to L1 vertebral level.
All Cases of complex congenital heart disease were included. The patients with associated Renal disease with Sr. Creatinine greater than 1.5mg/dl and allergic to iodinated contrast media were excluded from the study.

Non-ECG gated CT angiography: Non gated CT provides fast acquisition of cardiac and extracardiac structures in patient with CHD but lacks the visualization of small cardiac shunts, coronary structures because of heart motion artefacts. A pitch of 1 to 1.5 usually represents a good balance of image quality, radiation dose and acquisition time. Thicker collimation is preferred. Non gated CT is acquired during breath hold thus reduces motion artefacts. The radiation dose is usually less than 1msv in young children.

ECG gated CT angiography: In retrospective ECG-gated data acquisition is performed with continuous imaging table motion and spiral acquisition with overlap of the radiation beam on each spiral synchronized to the ECG. Hence low pitch values are necessary for gapless data acquisition and radiation dose is subsequently higher. However it provides artifact free image acquisition. Usually radiation dose is higher and is around 2-6msv for patients with CHD. In prospective ECG-gated data acquisition is performed in preselected cardiac phases. This results in relatively low effective radiation dose, which has been reported to be 1-3mSv in adults and 0.2-0.7mSv in newborns and infants. The major limitation in gated CT is that it is associated with longer imaging time. We preferred high pitch CT acquisitions with value of upto 3.5 . The high pitch acquisition mode is fast enough to reduce the acquisition time and therefore allow artifact free visualization .

Image Analysis: The imaging was reviewed on a workstation (Wizard, Siemens Medical Solutions).Images were reconstructed with aslice thickness of 0.75 mm and increment of 0.5 mm using a medium smooth-tissue convolution kernel (B26f). All images were transferred to an external work station (Multiple Modality Workplace, Siemens Healthcare, Forchheim, Germany) for post-processing. Multi-planar reformation (MPR), maximum intensity projection (MIP) and volume rendering (VR) were used for image interpretation.

Strategies for reduction of effective Radiation dose: We employed low radiation protocols by implementing modification of the radiation, acquisition and imaging parameters which include:

1. Restriction of z-axis coverage: Limiting z-axis coverage is an easy way to reduce the radiation dose. It reduces the dose by minimizing the overscanning.
2. Adaptation of imaging parameters according to body size: One of the easiest and most effective ways to limit radiation dose in CT for CHD imaging is to implement body size adaptive CT protocols. Patients with normal BMI 19-25kg/m^2, CT is performed at 120kVp and 220mAs/rotation.
3. ECG-based tube current modulation: The ECG pulsing technique has been reported to reduce radiation dose by upto 64%.
4. Case dose protocol/ employing low kvp: CT angiography in neonates is performed with kvp of 75-80kvp. Cardiac CT with tube voltage of 80kvp provides sufficient image quality when the tube current is output is adapted to patients body weight.

Radiation exposure: Dose-length product was recorded in each case. Estimated effective radiation dosages (mSv) were calculated for each scan using the following equation: (DLP×k) where k is constant and is 0.039 (infants <1 year old) or 0.026 (children >1 year old)[4,5].

RESULTS

- In our study there were total number of 50 patients out of which 29 were males (58%) and 21 were females (42%) with mean age of 2.7yrs (range from .1-13yrs). Among the 50 patients, 46 cases underwent Non-gated CT and 5cases underwent prospective ECG-gated CT angiography. All the patient underwent two diagnostic scan. One for diagnosing cardiac anomalies and another scan for diagnosing extracardiac anomalies and systemic malformations associated with complex congenital heart diseases. Dose length period was calculated for each individual exposure range from 4-18mGy*cm respectively. Total procedural DLP for each case was calculated .The median effective radiation dose for entire cohort was estimated to be 1.72 mSv.

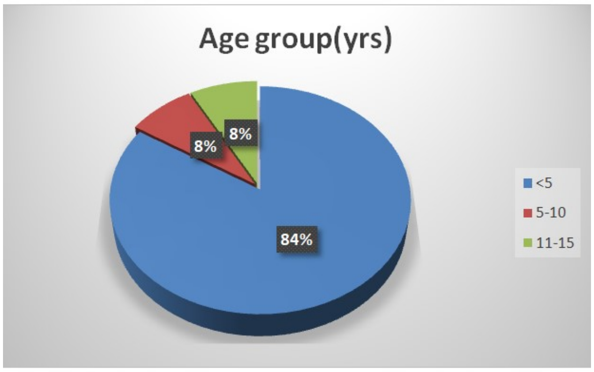

Figure 1. Pie chart showing percentage distribution of various age group

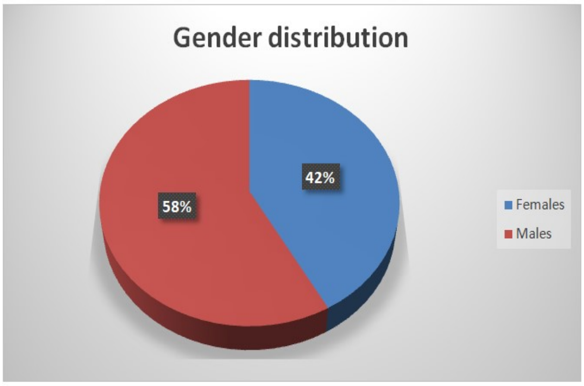

Figure 2. Pie chart showing distribution with respect to gender

Radiation dose parameters: The radiation dose parameters and effective radiation dose is calculated as mentioned in Table. The median CTDIvol was 0.45mGy (range, 0.14-0.95) and the median DLP was 9mGy*cm (ranging from 4-18) resulting in effective dose of 1.72 mSv (range, 0.99-2.88).

Table 1. Depicting the radiation dose parameters.

Radiation dose parameter	Median +/- interquartile range
$CTDI_{vol}$ (mGy)	0.45 (0.14-0.95)
DLP (mGy*cm)	9 (4-18)
Effective dose (mSv)	1.72(0.99-2.88)

$CTDI_{vol,}$ CT dose index volume; DLP, dose-length product.

Estimated effective radiation dose calculation: The individual estimated effective radiation dose was calculated. Two radiation exposures were given the respective values were calculated in order to get the average individual dose.(table:) The following imaging parameters were kept for each sacan as mentioned in table , inorder to get image optimization at lowest possible radiation dose. The mean CNR was 17.1+/- 7.5. All the examinations achieved a very good quality score of 1.4+/-0.6).

Table 2. Depicting the calculation of mean effective radiation dose (msv.mGy1.cm-1)

ERD	N	MEAN	MIN	MAX	SD
EXPOSURE-I	50	0.85	0.52	1.4176	0.19
EXPOSURE-II	50	0.88	0.47	1.4619	0.19
TOTAL ERD	50	1.72	0.99	2.88	0.37

Table 3. Image quality parameters

Image quality parameter	Mean +/- SD
Image noise (SD of HU)	29.8+/- 8.0
CNR	17.1 +/- 7.5
Subjective image quality score	1.4 +/-0.6

CNR, contrast to noise ratio; HU, Hounsfield units; SD, Standard deviation

DISCUSSION

- Cardiac CTA is becoming more and more established and is widely recommended in the preoperative management of CHD.
- Patients underwent cardiac MDCT procedure preceded by echocardiographic assessment either for confirmation of indeterminate echocardiography findings, depiction of complex congenital heart anomalies, better delineation of pulmonary arterial tree and MAPCA with calculation of effective radiation dose.

In our study cohort we calculate the effective radiation dose for each individual case. Dose-length product was recorded in each case. Estimated effective radiation dosages (mSv) were calculated for each scan using the following equation: DLPx k (conversion factor), k=0.039 (infants < 1 year old) or 0.026 (children > 1 year old). We give two exposures to each case, ist exposure was given to evaluate cardiovascular malformations and second exposure was give for evaluation of extra-cardiac and other systemic malformations. the average effective radiation dose for exposure-I was 0.85 ± 0.19 msv.mGy^{-1}.cm^{-1} with ERD ranging from (0.52 – 1.42msv). Average ERD for exposure II was 0.88 ± 0.19 msv.mGy^{-1}.cm^{-1} with ERD ranging from (0.45–1.46msv) with total mean effective radiation dose calculated was 1.71 ± 0.37 ranging from 0.99 – 2.8msv). our study is complemented by many previous studies done. Orly Goitein MD1et al in 2014 found the mean calculated effective dose related to the ECG-CTA scans was 1.4 ± 0.07 mSv (1.014–2.3 mSv). [(6)]Guilin Bu1 et al in 2016 calculated ED was 0.64 ± 0.21 mSv, ranging from 0.358 mSv to 1.196 mSv.[(8,9)]Pei Nie1 et al in 2014 found mean effective radiation dose of 0.29±0.08 mSv (range: 0.12 mSv–0.54 mSv).[(7)] Despite the advances, there is continuous challenge for the radiologists to optimize the radiation dose. Therefore we explored the feasibility of Dose reduction protocols without compromising the image quality. The image parameters were modified which include image noise, CNR and restriction of Z coverage. Further we also employ high pitch acquisition, ecg gated acquisition, body size adaptive protocols which include case dose protocol with low kvp setting. These parameter implementation lead to significant dose reduction in cardiac CTA.

CONCLUSION

The CT imaging protocol depends on the suspected cardiac defect, the patients age and level of cooperation. Cardiac CT with bolus tracking scan provides a radiation dose reducing method especially in neonates, For most of the patients the non-gated CT is adequate and benefits of obtaining functional information with ECG gated CT must overweigh the increased exposure.

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