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Original Article

To Assess the Relative Role of CTin The Evaluation of Congenital Heart Disease, and Compare Them with Echocardiography

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ABSTRACT

Aim: The aim of the present study was to assess the relative role of CT in the evaluation of congenital heart disease, and compare them with echocardiography.

Methods: This retrospective study included 62 consecutive patients with CHD who underwent cardiac CT scans between December 2015 and July 2017 at Dr. S. N. Medical Collage and Associated Hospitals, Jodhpur, Rajasthan. The procedure was explained to the patient / attendant and informed consent was taken. Detail history for contraindication of CT was specifically taken.

Results: In our study, the most common age group of presentation of congenital heart disease in 62 patients was >6-12-year age group (32.26%), followed by >1-6 month (19.35%), >1-6year (17.74%) and < 1 month age group (16.13%). The most common symptom observed in 62 patients was recurrent chest infection (66%) followed by rapid and shortness of breathing (50-55%). On general physical examination most, common signs observed in 62 patients were cyanosis (38%) and clubbing (14%). Cardiac CT of 62 patients with congenital heart disease revealed that 93.55% patients (58) had normal Situs (Situs solitus), one patient (1.61%) had Situs Inversus and three patients (4.84%) had Situs ambiguous. Analysis of 62 patients with congenital heart disease on cardiac CT revealed that 33.87% (21) patients arch of aorta and branching pattern anomalies. One patient (1.61%) had left predominant double aortic arch, 2 patients (3.23%) had left sided arch with bovine branching pattern and right sided aortic arch with mirror image branching pattern is seen in 6 patients (9.68%).

Conclusion: Hence our study shows that MDCT is useful not only as a non-invasive alternative to conventional angiography, but it can also serve as an accurate alternative to MRI if done using low dose protocols and in conjunction with echocardiography for functional assessment specially in low resource institutions.

Keywords: relative role of CT, evaluation of congenital heart disease, echocardiography

INTRODUCTION

The remarkable success of childhood intervention means that more than 90% of infants born with structural heart defects can now be expected to survive into adult life[1] and that more adults than children are now living with congenital heart disease (CHD).[2] Although the prognosis of CHD patients has dramatically improved, CHD patients often require surgical or percutaneous interventions after adolescence due to residual lesions or deterioration of a prosthesis.3 Among these lesions, stenotic or obstructive lesions sometimes become critical[4], CHD is the most common of congenital impairment. It was supply thought to such the major cause of mortality neonates was related to the atypical composition and/or function.[5]

Cross-sectional imaging became a critical in the diagnostic algorithm in assessment of CHD over the last period. Complimenting ECHO and, superseded the use of diagnostic cardiac catheterization.[6] Although cardiac MR is supply thought to the major imaging modality for CHD, increases in the speed of the CT and reductions in the radiation hazards rendered CT increasingly used for the assessment of CHD, in particular in neonates and young children.[6] Unlike ECHO, cardiac CT is window independent having wide FOV and provides good assessment of airway composition and coronaries.[7] For

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the mentioned reasons, cardiac CT is being increasingly utilized in CHD. Recent researches and guideline advices in its use.[8] A congenital heart disease (CHD), also known as a congenital heart anomaly or congenital heart defect, is a defect in the structure of the heart or great vessels that is present at birth but more often diagnosed subsequently.

The exact etiology of congenital heart defects is not fully understood yet. CHD is the most common major congenital anomaly and thus signifies a major global health problem.[9] There has been a tremendous improvement in treatment of CHD. A significant proportion of patients born with CHD may lead a normal, productive life if diagnosed early and appropriate medical/surgical intervention is instituted. Thus, early detection of CHD and timely intervention are important for a better outcome in patients with congenital heart disease.[10,11] Various imaging modalities are currently available including 2-dimensional Echocardiography, cardiac magnetic resonance imaging (MRI), and cardiac computed tomography (CT), all of which collectively provide invaluable information on cardiac anatomy and hemodynamics. Advanced imaging plays a role in diagnosis, pre-operative planning and determines the need and frequency of follow-up. The primary objective of this study was to study the spectrum of congenital heart diseases using 2-dimensional Echocardiography and cardiac CT in a tertiary care Centre of central Maharashtra region of India. CHD may be diagnosed at virtually any age. Majority of conditions are usually discovered in neonatal period; other conditions are identified during infancy, childhood or sometimes in adult life.[12]

The aim of the present study was to assess the relative role of CT in the evaluation of congenital heart disease, and compare them with echocardiography.

MATERIALS AND METHODS

This retrospective study included 62 consecutive patients with CHD who underwent cardiac CT scans between December 2015 and July 2017 at Dr. S. N. Medical Collage and Associated Hospitals, Jodhpur, Rajasthan. The procedure was explained to the patient / attendant and informed consent was taken. Detail history for contraindication of CT was specifically taken.

Patients admitted to or attending OPD in Dr. S. N. Medical College, Jodhpur and associated hospitals (Mathura Das Mathur Hospital, Mahatma Gandhi Hospital and Umaid Hospital) with clinically suspected/detected congenital heart disease. The study was performed on all patients after written informed consent.

INCLUSION CRITERIA

Patients suspected or diagnosed of having complex congenital heart disease on examination and echocardiography.

EXCLUSION CRITERIA

- Hemodynamically unstable patients.
- Surgically repaired patients.
- Patients with known hypersensitivity to iodinated contrast media.
- Severe renal impairment.
- Pregnant patient

CT MACHINE

All the CT scans in this study were performed using PHILIPS Ingenuity core 64-slice multi detector CT with Philips windows workstation and Philips Intel space software.

METHOD

All MDCT evaluations are routinely preceded by consultation with our paediatric cardiology colleagues. Most of the studies were performed to answer specific anatomic questions raised by an inconclusive echocardiographic evaluation.

CT angiographic studies were performed with non-ionic contrast material with iodine concentrations of 350 mg I/mL administered at a dose of 1- 2 mL/kg. All our procedures were performed with a 64-MDCT PHILIPS Ingenuity core scanner. In the initial half of the study the CT angiography of children with CHD was done according to the default pulmonary embolism protocol set in the machine by the manufactures for each particular age group. However, it was realized that the effective radiation dose of examination was unacceptably high for the paediatric age group.

Hence the protocol was modified to low dose protocols specifically for different age groups. In general,kVp settings for children <1 year was kept 80 kVp, between 1-10years it was kept as 100 kVp and above 10 years it was kept as 120 kVp. The mAS settings were also modified and reduced according to age, weight and kVp settings. Automated dose regulation methods are also used to reduce the radiation. Radiation exposure was also reduced by using: Fast table speed, thin detector collimation, pitches > 1; slice thickness 1mm; and idose. These together with the FOV were modified to keep the DLP within acceptable range for each age group during planning of scan. Full FOV NCCT was not acquired and bolus tracker was placed based on a placed in the estimated position of the right ventricle after taking a 5 cm NCCT scan at the widest cardiac silhouette. All are scans except one were non-ECG gated and single phase and single acquisition. One patient with suspected coronary artery anomaly was done with retrospective ECG gating.

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Hence in later half of the study most of the scans were done with low dose protocol. All patients which were done with low dose protocol had acceptable quality images depicting all the anatomical aberrations clearly. After recording the scan DLP from dose information chart effective radiation dose in mSV was calculated by radiation dose calculator of xrayrisk.com website using pulmonary embolism chest CT category.

Criteria used in this study to classify patient doses according to age category

Age	Low	Intermediate	
≤ 1 Month	≤0.5	0.6-1	>1
>1-6 Month	≤1	>1-2	>2
>6-12 Month	≤2	>2-3	>3
>1-6 year	≤3	>3-5	>5
>6-12 year	≤3	>3-6	>6
>12-18 year	≤4	>4-7	>7
>18 year	≤5	>5-8	>8

In few of the new born and infants < 6 months contrast material was hand-injected through a 18 to 24-gauge IV needle, When power injection is possible, an automated bolus tracking technique is used at an injection rate of 1-2.5 mL/sec, the bolus-tracking device is placed in the estimated position of the right ventricle after taking a 5 cm NCCT scan at the widest cardiac silhoutee. Three-dimensional reconstructions were created for all patients and systematically analyzed using advanced processing techniques.

Functional assessment was not performed due to unavailability of adequate software for accurate and reproducible ventricular function assessment. Oral chloral hydrate or Short-term IV sedation with midazolam (Dose: 0.05-0.1 mg/kg IV: Max: 0.6 mg/kg) was used, particularly in children under 5 years of age, and the imaging was performed during quiet breathing. Older children required only breath holding during the scan to improve image quality.

Post processing & Reformatting Techniques

The CT volume data were transferred to a commercially available workstation Various image reformatting techniques, including linear or curved planar reformatting, maximum intensity projection (MIP), minimum intensity projection, shaded surface display, and volume rendering (VR), were used depending on target structure and purpose. The plane of the reformatted image was adjusted to correspond to the long axis of the structure of interest. Curved planar reformation was used to evaluate curved structures such as the pulmonary artery system, MIP was used mainly for evaluation of the cardiovascular structures, and minimum intensity projection was used to evaluate the airway and lung parenchyma.

For three-dimensional reformatting, shaded surface display was used to evaluate the airway and lung, whereas VR was used to evaluate the cardiovascular structures. Thin-section multiplanar reformatting was used to accurately measure the diameter or an area of the structure in question. Image reformatting techniques were selected on a case-by-case basis to avoid obtaining faulty information. On average, image reformatting took about 1 hour per patient. Image interpretation was done by two radiologist one with experience of interpreting cardiac CTs for more than 15 years other with experience of 1.5-2 years.

RESULTS

Table 1: Baseline characteristics

Age	No. Of patients	Percentage
≤ 1 Month	10	16.13
>1-6 Month	12	19.35
>6-12 Month	6	9.68
>1-6 year	11	17.74
>6-12 year	20	32.26
>12-18 year	1	1.61
>18 year	2	3.23
Clinical history		
Shortness Of Breath	32	51.61
Rapid Breathing	35	56.45
Delayed Growth	4	6.45
Recurrent Chest Infection	41	66.13

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Bluish Discoloration of Skin	25	40.32
Feeding difficulties	11	17.74
GPE		
Cyanosis on Rest/Cry	25	40.32
Clubbing	9	14.52
Enlarged abdominal wall collateral	0	0.00
Facies	1	1.61
No signs	27	43.55
Situs		
Solitus	58	93.55
Inversus	1	1.61
Ambiguous	3	4.84
Visceral isomerism		
Normal	58	93.55
Ambiguous	3	4.84
Inversus	1	1.61

In our study, the most common age group of presentation of congenital heart disease in 62 patients was >6-12-year age group (32.26%), followed by >1-6 month (19.35%), >1-6year (17.74%) and < 1 month age group (16.13%). The most common symptom observed in 62 patients was recurrent chest infection (66%) followed by rapid and shortness of breathing (50-55%). On general physical examination most, common signs observed in 62 patients were cyanosis (38%) and clubbing (14%). Cardiac CT of 62 patients with congenital heart disease revealed that 93.55% patients (58) had normal Situs (Situs solitus), one patient (1.61%) had Situs Inversus and three patients (4.84%) had Situs ambiguous. Cardiac CT of 62 patients with congenital heart disease revealed that 58 patients (93.55%) had normal visceral isomerism, one patient (1.61%) had Inverse isomerism and 3 patients (4.84%) had ambiguous type isomerism. One patient of the Situs ambiguous had left sided isomerism with bilateral left sided atrial morphology of and bronchial branching pattern.

Table 2: Arch of aorta and branching pattern on cardiac CT

Arch of aorta & branching pattern	No. Of patients	Percentage
Normal	41	66.13
Left predominant double aortic arch forming a complete vascular ring	1	1.61
Left sided and LVA directly originate from the arch of aorta	5	8.06
Left sided with bovine arch	2	3.23
Right sided aortic arch with mirror image branching pattern	6	9.68
Interrupted aortic arch	1	1.61
COA	4	6.4
Aberrant right subclavian artery	2	3.23

Analysis of 62 patients with congenital heart disease on cardiac CT revealed that 33.87% (21) patients arch of aorta and branching pattern anomalies. One patient (1.61%) had left predominant double aortic arch, 2 patients (3.23%) had left sided arch with bovine branching pattern and right sided aortic arch with mirror image branching pattern is seen in 6 patients (9.68%).

Table 3: Comparison of CT and Echocardiography in VSDs

Types of VSD	On CT	On Echo	P value
Membranous	25	20	0.455
Muscular	6	6	1.273
AV canal type (inlet)	3	3	1.320
Conal-septal (Outlet)	1	0	0.495
Mixed	3	4	1.000
Indeterminate	0	4	0.118
Sub Truncal	3	1	0.618

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Total	41	38	---

Analysis of 62 patients revealed that 66.13% (41) patients had VSD. Out of 41 VSDs membranous type of VSD is more common than other type of VSDs. Most of membranous type of VSDs is found in the form of sub aortic VSD. Least common is outlet type VSD which had associated anomaly of Cortriatrium dexter.

Table 4: Comparison of CT and Echocardiography in venous connection abnormalities

Venous connections anomalies	CT	ECHO	p value
IVC	2	1	1.000
SVC	6	1	0.114
Coronary sinus	0	0	-
Pulmonary veins	8	5	0.395
Total	16	7	

Analysis of 62 patients with congenital heart disease on cardiac CT had revealed that 16 patients had venous connection anomalies. Echocardiography diagnosed only 7 venous anomalies but the difference is not statistically significant. Echocardiography diagnosed 1 IVC anomaly which was interrupted IVC with azygous continuation, while CT also diagnosed other left sided IVC along with interrupted IVC with azygous continuation.

Table 5: Comparison of CT and Echocardiography in Pulmonary anomalous venous connections

Pulmonary venous abnormalities		CT	ECHO
TAPVC	Supra cardiac	3	3
	Infra cardiac	1	0
	Cardiac	0	1
PAPVC	Supra cardiac	0	1
	Infra cardiac	0	0
	Cardiac	2	0

Out of 6 patients with pulmonary veins abnormalities, echocardiography wrongly diagnosed 1 patient of Infracardiac TAPVC as cardiac type TAPVC and 1 patient of supracardiac TAPVC as Supracardiac PAPVC. Echocardiography also wrongly diagnosed 1 patient of cardiac type PAPVC as supracardiac TAPVC.

Table 6: Comparison of CT and Echocardiography in intra cardiac lesions

Intra cardiac		CT	ECHO	p value
Shunt lesions	ASD	23	17	0.336
	VSD	41	38	0.709
Cortriatrium	Dexter	1	1	-
	Sinister	2	2	-
Interatrial septal aneurysm		2	2	-
VSD With muscular bands		2	2	-
HOCM		1	1	-
Valvular and subvalvular pulmonary stenosis		22	16	0.33
Ebstein anomaly		1	1	-

Analysis of 62 patients with congenital heart disease on cardiac CT revealed that 23 patients had ASD on cardiac CT imaging, while echocardiography detected ASD only in 17 patients.

Table 7: Comparison of CT and Echocardiography in Ventricular arterial connection abnormalities

Ventricular arterial connection abnormalities	CT	ECHO	p value
TOF	18	14	0.538
DORV	4	3	-
TA	3	2	-
TGA	1	1	-

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Echocardiography fails to detect 4 TOF lesions out of 18 patients (4/18%) and 1 truncus arteriosus lesion. However, there is no significant statistically difference.

Table 8: Comparison of CT and Echocardiography in Extra cardiac arterial anomalies

Extra cardiac arterial anomalies	CT	ECHO	p value
APW	2	1	1.000
PDA	14	13	1.000
Pulmonary atresia	5	4	1.000
Pulmonary artery dilatation	15	11	0.508
MAPCAS	13	0	**<0.0001**
Arch of aorta & branching pattern anomaly	21	2	**0.0001**

Total extracardiac arterial anomalies detected on CT angiography were 71 including APW (2), PDA (14), pulmonary atresia (5), and pulmonary artery dilation (15), MAPCAS (13) and arch of aorta and branching pattern anomalies (21). Echocardiography had detected only 42% (30/71) extracardiac arterial anomalies as compare to CT.

DISCUSSION

Congenital heart disease (CHD) is reported with an incidence of 4 to 50 per 1,000 live births—depending primarily on the number of small ventricular septal defects included in the series[13]and it is estimated that 85% of children with CHD will survive to adulthood due to improvements in medical management and surgical procedures.[14] Around 50% of these children will require follow-up in adult life.[15]

In our study, the most common age group of presentation of congenital heart disease in 62 patients was >6-12-year age group (32.26%), followed by >1-6 month (19.35%), >1-6year (17.74%) and < 1 month age group (16.13%). The most common symptom observed in 62 patients was recurrent chest infection (66%) followed by rapid and shortness of breathing (50-55%). On general physical examination most, common signs observed in 62 patients were cyanosis (38%) and clubbing (14%). Cardiac CT of 62 patients with congenital heart disease revealed that 93.55% patients (58) had normal Situs (Situs solitus), one patient (1.61%) had Situs Inversus and three patients (4.84%) had Situs ambiguous. Cardiac CT of 62 patients with congenital heart disease revealed that 58 patients (93.55%) had normal visceral isomerism, one patient (1.61%) had Inverse isomerism and 3 patients (4.84%) had ambiguous type isomerism. One patient of the Situs ambiguous had left sided isomerism with bilateral left sided atrial morphology of and bronchial branching pattern.

Analysis of 62 patients with congenital heart disease on cardiac CT revealed that 33.87% (21) patients arch of aorta and branching pattern anomalies. One patient (1.61%) had left predominant double aortic arch, 2 patients (3.23%) had left sided arch with bovine branching pattern and right sided aortic arch with mirror image branching pattern is seen in 6 patients (9.68%). Analysis of 62 patients revealed that 66.13% (41) patients had VSD. Out of 41 VSDs membranous type of VSD is more common than other type of VSDs. Most of membranous type of VSDs is found in the form of sub aortic VSD. Least common is outlet type VSD which had associated anomaly of CortriatriumDexter. Analysis of 62 patients with congenital heart disease on cardiac CT had revealed that 16 patients had venous connection anomalies. Echocardiography diagnosed only 7 venous anomalies but the difference is not statistically significant. Echocardiography diagnosed 1 IVC anomaly which was interrupted IVC with azygous continuation, while CT also diagnosed other left sided IVC along with interrupted IVC with azygous continuation. In the study by Al-Azzazy MZ et al[16], for comparison of MDCT and angiography in 24 children with coarctation of aorta and other anomalies, 1 small VSD out of 4 cases was missed and all cases of ASD were identified. Garg et al[17], studied the MDCT vs.CCA in CHD diagnosis and found fewsmall VSDs were missed on MDCT.

Out of 6 patients with pulmonary veins abnormalities, echocardiography wrongly diagnosed 1 patient of Infracardiac TAPVC as cardiac type TAPVC and 1 patient of supracardiac TAPVC as Supracardiac PAPVC. Echocardiography also wrongly diagnosed 1 patient of cardiac type PAPVC as supracardiac TAPVC.These results are similar to Osama Ayman[18] which also quoted that MDCT correctly depicted the TAPVR and PAPVR types of pulmonary venous anomalies with sensitivity 100%, and specificity 100%. The specificity of echocardiography was 50% for both findings.

Compared to CT scan, echocardiography failed to detect all MAPCAs and most of arch and branching pattern anomalies and this difference were statistically significant. Hence in these two types of extracardiac arterial anomalies CT is a better modality than echocardiography. These results are similar to Nakhla Osama Lamie et al[19] which also quoted that for MAPCAs and arch and branching pattern anomalies, CT is a better modality than echocardiography.Analysis of 62 patients with congenital heart disease on cardiac

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CT revealed that 23 patients had ASD on cardiac CT imaging, while echocardiography detected ASD only in 17 patients.Echocardiography fails to detect 4 TOF lesions out of 18 patients (4/18%) and 1 truncus arteriosus lesion. However, there is no significant statistically difference. Total extracardiac arterial anomalies detected on CT angiography were 71 including APW (2), PDA (14), pulmonary atresia (5), and pulmonary artery dilation (15), MAPCAS (13) and arch of aorta and branching pattern anomalies (21). Echocardiography had detected only 42% (30/71) extracardiac arterial anomalies as compare to CT.

CONCLUSION

Amongst noninvasive methods, magnetic resonance (MR) imaging is an alternative to MDCT. However, the successive breath holds may be impossible or less reproducible in my patients, especially in infants who required profound sedation. In patients with respiratory symptoms, the profound sedation might increase the risk of impairment of functional status and the necessity of assisted ventilation. MDCT was performed in quiet or sleeping infants and the speed of imaging acquisition contributed to the production of high-quality diagnostic imaging. Hence our study shows that MDCT is useful not only as a non-invasive alternative to conventional angiography, but it can also serve as an accurate alternative to MRI if done using low dose protocols and in conjunction with echocardiography for functional assessment specially in low resource institutions.

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