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To Evaluate the Role of Cardiac CT Angiography in the Pre-Op Evaluation of Congenital Heart Disease and to Compare its Diagnostic Accuracy with Echocardiography

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Abstract

Background: The present study was undertaken to evaluate the role of Cardiac CT Angiography in the pre-op evaluation of congenital heart disease and to compare its diagnostic accuracy with that of Echocardiography. **Material and Methods:** It included 50 patients of CHD previously diagnosed by Echo on whom Contrast Enhanced Cardiac CT Angiography was performed using a Pulmonary Angiography protocol in 64 slice GE MDCT Scanner. The axial images obtained by the bolus tracking method were reconstructed into MPR, MIP and Volume rendered images. So obtained images were analysed for interpretation of Congenital Cardiovascular Heart Disease. **Results:** A total of 200 anomalies were present with 105 intracardiac and 95 extracardiac anomalies in the patients on post-operative evaluation. The diagnostic accuracy rate of Echo for intracardiac anomalies was 98% and for extracardiac anomalies was 60%.MDCT had a diagnostic accuracy of 95.2% for intracardiac anomalies and a diagnostic accuracy rate of 96.8% for extracardiac anomalies. **Conclusion:** Therefore while the diagnostic accuracy of Echo and MDCT for Intracardiac anomalies goes hand in hand, the diagnostic accuracy of MDCT for extracardiac anomalies was superior to that of Echo.

Keywords: CHD, ECHO, Contrast Enhanced Cardiac CT Angiography, Pulmonary Angiography, Congenital Cardiovascular Heart Disease.

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Introduction

Congenital heart diseases (CHD) refer to structural or functional heart diseases which are present at birth or may be discovered later. These are primarily seen in neonates, infants and children. The burden of congenital heart disease in India is likely to be enormous, due to very high birth rate. This heavy burden emphasizes the importance if this group of heart diseases. The reported incidence of CHD is 1.25 to 3.9/1000 live births and as many as 75 per 1000 live births have simple lesions like Ventricular Septal Defect. Its prevalence is more in pre-term neonates than in term neonates. Currently, it is estimated that approximately 180,000 children are born with CHD each year in India. Nearly one third to half of these CHD is critical, requiring intervention in first year of life itself.

Improved medical and surgical care in the past decade has decreased early and late mortality resulting in the increased number of patients surviving well into adulthood with both simple and complex forms of CHD. Rapid advances have taken place in the diagnosis and treatment of CHD in the last six decades. There are diagnostic tools available today by which an accurate diagnosis of CHD can be made even before birth. With currently available treatment modalities, over 75% of infants born with critical heart disease can survive beyond first year

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of life. As a result of these improvements, the number of adult survivors with CHD surpassed the number of pediatric patients with CHD in 2003.

Given the wide diversity of congenital lesions, the variety of surgical palliative techniques developed, subsequent modifications, and innovative trans catheter techniques, noninvasive imaging is essential to the assessment of CHD. Therefore evaluation of the optimal noninvasive imaging tool has become an active and ongoing field of study in this expanding patient population.

The initial imaging algorithm for patients with suspected CHD includes a chest radiograph and subsequent Trans-thoracic echocardiography (TTE). TTE is readily available, portable, and noninvasive. It can provide detailed anatomic information and characterization of hemodynamic parameters through Doppler flow studies. However, the technique is operator-dependent and limited by acoustic window parameters (thoracic deformities, air- filled lung, sternal wires, and obesity) and inability to depict extra cardiac vascular structures. Trans-esophageal Echocardiography (TEE) offers higher spatial resolution than TTE, but it is a more invasive procedure and it still has limitations in examining the systemic and pulmonary vascular systems. Cardiac catheterization was previously the gold standard for cardiac evaluation, but this procedure carries the inherent risks of trauma to vascular structures and sedation or general anesthesia is often required for prolonged procedural times. Its invasive nature has limited its widespread application due to immediate mortality rate of 0.1%. Magnetic resonance imaging on the other hand provides noninvasive visualization of the morphologic changes in patients with CHD, overcoming the limitations of Echocardiography. It offers anatomic and functional information and is valuable in the evaluation of valvular and myocardial function, but it is time-consuming (40 min to 1 hour) and requires general anaesthesia in critically ill and thermally unstable pediatric patients with heart failure, cyanosis, and orthopnea and may not be tolerable. Finally MRI is contraindicated in patients with pacemakers, post-operative stents and implantable cardioverter-defibrillators. There are several advantages of CT compared with MRI. CT is more available and less time consuming (2-4min) than MRI. The use of multidetector CT technology shortens examination times, increases spatial resolution, and enables superb reconstructions. It allows for a more complete evaluation of lung parenchyma than does MRI. CT unlike MRI is not hampered by postoperative metal artifacts. CT also has the disadvantage of radiation exposure as well as the necessity for intravenous administration of contrast material. Nevertheless, CT is enjoying broader use because of its ease of use and widespread availability. Thus, an understanding of the CT features of CHD is essential to ensure a correct diagnosis. Therefore, this technique should be strongly considered in patients with poor echocardiographic windows and contraindications to CMR.

Material and Methods

This prospective study of “Pre-op evaluation of congenital heart disease by cardiac multidetector computed tomography angiography” was conducted in the Department of Radiodiagnosis, Chirayu Medical College & Hospital, Bhopal & LN Medical College Bhopal, and Madhya Pradesh, India over a period of two years from July 2020 to July 2022. This is a prospective study of 50 patients who presented at our hospital with symptoms of Congenital Heart Disease previously diagnosed by 2D Transthoracic Echocardiography. The study was approved by the Ethics committee of the institutions.

The procedure, possible adverse effects of contrast medium injection and radiation exposure was explained to the patients/parents by the Radiologist. Informed signed consent was taken prior to conducting the scan. Adequate pre-procedural counseling to the parents alleviated anxiety and ensured patient co-operation in elderly children.

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- **Inclusion criteria**: All patients presenting to the hospital with congenital heart disease referred for Cardiac MDCT were included, regardless of whether they were referred to or born in our hospital.
- **Exclusion criteria**:

1) Patients coming for Post-operative follow-up
2) Patients with Post-op complications.
3) Patients coming with recurrent disease.

- A detailed history of the patient including signs and symptoms, detailed physical examination, biochemical investigation (if required), radiological investigations which included Chest Radiograph and 2D Transthoracic Echocardiography of the Heart were recorded and tabulated as in the proforma shown below.
- 50 confirmed cases of CHD were selected for the study on whom Contrast Enhanced CT Angiography was performed.

Correlation was made with their respective 2D Echocardiograms.

- All the findings in each case with both of these imaging modalities were reviewed and compared, the surgical confirmation, which was used as the reference standard, was available in all patients.
- The segmental approach, which is widely used in the imaging work-up of congenital heart disease, consists of these steps in the evaluation of cardiac anatomy.

Results

Table 1: Presenting Complaints

S. No	Presenting Complaints	No of Cases	% of Cases
1	Respiratory Distress	32	64%
2	Cyanosis	24	48%
3	Congestive Heart Failure	18	36%
4	Respiratory Infections	15	30%
5	Failure To Thrive	9	18%

Table 2: ECHO Findings in Intracardiac Anomalies

S. No	Intracardiac Anomalies	No of Anomalies
1.	ASD	10
2.	VSD	20
3.	TOF Related Anomalies	48
4.	Atrio-Ventricular Canal Defect	12
5.	Tricuspid Atresia	1
6.	Ebstein's Anomaly	1
7.	Aortic Stenosis	2
8.	Pulm Stenosis	9
	Total	103

Table 3: ECHO Findings in Extracardiac Anomalies

S. No	Extracardiac Anomalies	No of Anomalies
1.	SVC Related	-
2.	IVC Related	3
3.	Aortic Arch Anomalies	14
4.	Patent Ductus Arteriosus	13
5.	Pulmo Venous Drainage Anomalies	5
6.	MAPCA's	13

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7.	Other Anomalies	9
8.	Total	57

Table 4: MDCT Findings in Intracardiac Anomalies

S. No	Intracardiac Anomalies	No of Anomalies
1.	ASD	9
2.	VSD	20
3.	TOF Related Anomalies	46
4.	Atrio-Ventricular Canal Defect	12
5.	Tricuspid Atresia	1
6.	Ebstein's Anomaly	1
7.	Aortic Stenosis	2
8.	Pulm Stenosis	9
	Total	100

TABLE 5: MDCT Findings in Extracardiac Anomalies

S. No	Extracardiac Anomalies	No of Anomalies
1.	SVC Related	10
2.	IVC Related	5
3.	Aortic Arch Anomalies	22
4.	Patent Ductus Arteriosus	14
4.	Pulm Venous Drainage Anomalies	6
5.	MAPCA's	26
6.	Aorto-pulmonary Window Defect	2
7.	Other Anomalies	7
8.	Total	92

Table 6: Comparison of ECHO With MDCT

S. No	Anomalies	No of Anomalies On ECHO	No of Anomalies On MDCT	Follow Up
1.	Intracardiac	103	100	105
2.	Extracardiac	57	92	95
	Total	160	192	200

Table 7: Comparison of Diagnostic Accuracy of ECHO With MDCT

S. No	Anomalies	Diagnostic Accuracy of ECHO	Diagnostic Accuracy of Mdct
1.	Intracardiac	98.09%	95.2%
2.	Extracardiac	60%	96.8%

The following observations were recorded from our study:
Majority of patients in our study belonged to the age group of 1 – 5 years (26%) followed by children less than 6 months of age (22%). Males predominated in our study with 68% of total patients. The most common presenting complaint among the patients was Respiratory distress (Dyspnea) in 68% of them followed by Cyanosis in 48% patients. Echocardiography performed on all the 50 patients revealed a total of 160 anomalies with 103 intracardiac anomalies and 57 extracardiac anomalies.
On MDCT a total of 192 anomalies of which 100 intracardiac anomalies and 92 extracardiac anomalies were detected. Dextrocardia was present in 10 patients i.e. 20% of them. In the rest

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Levocardia was present. Out of ten patients with dextrocardia, Situs abnormality was noted in 6. There were two cases each of Situs inversus, Right Isomerism and Left Isomerism. Tetralogy of Fallot (TOF) was the most common congenital heart disease seen accounting for a total of 48 anomalies in 19 patients. Followed by TOF was Ventricular septal defects accounting for 20 anomalies. Perimembranous VSD was the most common type (65%) followed by Muscular VSD seen in 25% of VSD patients.

A total of 9 atrial septal defects were found. Ostium secundum was the most common type .A total of 200 anomalies were present with 105 intracardiac and 95 extracardiac anomalies in the patients on post-operative evaluation.The diagnostic accuracy rate of Echo for intracardiac anomalies was 98% and for extracardiac anomalies was 60%.MDCT had a diagnostic accuracy of 95.2% for intracardiac anomalies and a diagnostic accuracy rate of 96.8% for extracardiac anomalies.Therefore while the diagnostic accuracy of Echo and MDCT for Intracardiac anomalies goes hand in hand, the diagnostic accuracy of MDCT for extracardiac anomalies was superior to that of Echo.

Statistical Analysis

The collected data was summarized by using frequency, percentage, mean & S.D. To compare the qualitative outcome measures Chi-square test or Fisher's exact test was used. To compare the quantitative outcome measures Independent t test was used. If data was not following normal distribution, Mann Whitney U test was used. SPSS version 22 software was used to analyse the collected data. p value of <0.05 was considered to be statistically significant.

Discussion

Advances in surgical techniques and clinical management continue to improve the survival and quality of life of pediatric patients with congenital heart disease (CHD). In recent years, cardiac computed tomographic angiography (CTA) has been increasingly used for pre-operative evaluation in these patients. Cardiac CTA is particularly beneficial when alternative imaging modalities, such as Echocardiography or Magnetic resonance imaging (MRI), are limited or contraindicated. Rapid technical advancements in multidetector-row computed tomography i.e. MDCT have enhanced noninvasive imaging of children with CHD by,[1] improving temporal and spatial resolution;[2] decreasing scan times;[3] reducing need for sedation; and,[4] generating high-quality, visually accessible, and anatomically meaningful two-dimensional and three-dimensional images .

Although the role of CT in the evaluation of pediatric CHD is being redefined and expanded, there are several generally accepted clinical indications for which the benefits of imaging outweigh the risks. CT can be useful before a reoperation to assess altered anatomic features related to previous surgery. In light of these advances and its widespread availability, MDCT has become an important complementary imaging technique for CHD patients going for surgical repair.

Kumar A et al sought to examine the reliability and correlation of echocardiography (ECHO) and computed tomography angiography (CTA) measurements with those obtained by cardiac catheterization and angiography (CCA).Computed tomography angiography and CCA measurements for iPAnn, iRPA, NI, MGR, pRV/pLV, and *Z*-score were comparable with each other while ECHO parameters were significantly lower than CCA. However, iLPA diameter was significantly underestimated by ECHO and overestimated by CTA. Correlational analysis showed stronger correlation between CTA- and CCA-derived PVD as against ECHO, Conclusion was that for unrepaired TOF physiology patients weighing more than 10 kg, CTA-acquired PVD are reliable and comparable with CCA except for DA for which ECHO is non-inferior. Non-invasive modalities though are inferior to CCA for LPA

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sizing. Utilizing derived equations, precise estimation of PVD can be carried out using non-invasive tools.

Liddy S et al did the assessment of cardiac masses by cardiac CT and CMR including pre-op 3D reconstruction and planning. The purpose of this review is to,[1] review the recent evidence examining the use of CT and CMR in the assessment of a suspected cardiac mass,[2] summarize the typical imaging features of the most common cardiac masses, and,[3] examine the latest developments in the use of three-dimensional reconstructions and models in the preoperative assessment of a cardiac mass. CT and CMR are complementary tools in the evaluation of cardiac masses. CMR is the preferred initial imaging modality due to its versatile imaging planes and superior tissue characterization. CT better depicts calcification and has a higher spatial resolution compared with CMR, which is of particular importance in preoperative planning. CT also offers a valuable alternative in those with contraindications to CMR.

Cardiovascular applications of this technology development include the use of patient-specific 3D models for medical teaching, exploration of valve and vessel function, surgical and catheter-based procedural planning, and early work in designing and refining the latest innovations in percutaneous structural devices. In this review, Vukicevic M et al discuss the methods and materials being used for 3D printing today. We discuss the basic principles of clinical image segmentation, including coregistration of multiple imaging datasets to create an anatomic model of interest. With applications in congenital heart disease, coronary artery disease, and surgical and catheter-based structural disease, 3D printing is a new tool that is challenging how we image, plan, and carries out cardiovascular interventions.

Echocardiography has proven to be a useful tool for this purpose and its utility has expanded drastically with the development of better technology and newer techniques. As the prevalence of adult congenital heart disease continues to grow secondary to advances in surgical and diagnostic techniques, it is important for a physician to supplement their examinations with non-invasive imaging techniques to assess their patients. Although a number of these patients have regular cardiology followup, some may be new patients that do not even know their cardiac history. In this article, Mcleod G et al highlight some of these advancements including 2D echocardiography, agitated saline, contrast echocardiography, stress, and 4D, in addition to how each modality can help assess key aspects of the structure and function of a congenital heart defect.

Pignatelli RH et al compared the role of echocardiography versus MRI for the diagnosis of congenital heart disease. Echocardiography and MRI continue to provide improved means of anatomic and functional assessment in children and adults with congenital heart lesions. This review reports some of the recent advances in tissue Doppler, strain rate, and integrated backscatter, and highlights exciting current and future potential developments in their application. We also discuss advances in MR in evaluation of cardiac anatomy and function in congenital heart disease.

Lai WW et al studied the use of Echocardiography in pediatric and congenital heart disease. In a similar study, Sharma S et al studied role of echocardiography in prenatal screening of congenital heart diseases and its correlation with postnatal outcome.Fetal echocardiography performed during second trimester aims at early diagnosis of congenital heart disease which is instrumental in proper planning of delivery, perinatal care and counselling of parents. The overall incidence of CHD in study population was 15 per 1000The CHD cases with ECA were significantly of low birth weight, born preterm and delivered by Lower Segment Caesarean Section (LSCS).Study conclude that fetal echocardiography should be an integral part of every second trimester anomaly scan for all pregnant females irrespective of their risk factors. The associated ECAs are another factor that causes increased mortality both in antenatal and neonatal life, again warranting an early fetal echo.

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Gutgesell HP et al assessed the accuracy of 2-dimensional (2-D) echocardiography in the evaluation of cardiac anatomy in patients with congenital heart disease. The most common lesions and the sensitivity and specificity of echocardiography were: patent ductus arteriosus, 41 patients (83% and 100%, respectively), ventricular septal defect, 35 patients (86% and 100%); atrial septal defect, 26 patients (85% and 99%); pulmonary valve stenosis, 25 patients (77% and 97%), transposition of the great arteries, 16 patients (100% and 100%); and total anomalous pulmonary venous connection .Pulmonary valve stenosis and patent ductus arteriosus are the lesions most likely to be misdiagnosed by ultrasound studies relying on imaging alone. To quench the thirst of an optimal, non-invasive, faster, easily reproducible and widely available imaging tool, we attempted to evaluate the role of cardiac CT Angiography in the pre-operative evaluation of Congenital Heart Disease. The primary objective of our study was to assess the role of contrast enhanced Cardiac CT Angiography in delineating the entire spectrum of Congenital Heart Diseases and to establish its competency in comparison to 2D Transthoracic Echocardiography for optimum and tailored pre-surgical planning where Echocardiographic data was insufficient for pre-op surgical planning. The pros and cons of each modality were compared with risk benefit ratio to arrive at a feasible conclusion. The obtained data was interpreted and tabulated for analysis of results.

In the present study, the most common age group of patients presenting with CHD was in 1-5 years range constituting 26% of the cases followed by children less than 6 months of age with 22% of cases. Males predominated in our study with 68% of total patients. The most common presenting complaint among the patients was Respiratory distress (Dyspnea) in 68% of them followed by Cyanosis in 48% patients. A maximum of 57 extracardiac anomalies were detected of which Aortic arch anomalies (n=14) contributed the most followed closely by Patent ductus arteriosus (n=13). This information obtained by Echocardiography was inadequate for surgical repair. Therefore the patients were subjected for Cardiac CT Angiography to delineate the entire anatomical profile.

MDCT performed on all 50 pts revealed a total of 192 anomalies of which 100 intracardiac anomalies and 92 extracardiac anomalies were present. There were 93 extracardiac anomalies detected of which MAPCA's formed the maximum number of anomalies (n=26) being seen in more than half of patients (52%). The results of Echocardiography and MDCT were compared with the anomalies found on surgical follow up. A total of 200 anomalies were present with 105 intracardiac and 95 extracardiac anomalies in the patients on post-operative evaluation.

On comparison, Echocardiography missed 2 intracardiac anomalies out of 105 and was correctly able to diagnose 103 anomalies. Whilst out of 95 extracardiac anomalies it was able to pick up only 57 of them therefore precluding its role in extracardiac evaluation. On calculations the diagnostic accuracy rate of ECHO for intracardiac anomalies was 98% and for extracardiac anomalies was 60%.MDCT on the other hand detected 100 intracardiac anomalies out of 105 leading to diagnostic accuracy of 95.2%. Out of 95 extracardiac anomalies MDCT was able to detect 92 of them giving a diagnostic accuracy rate of 96.8%. Therefore MDCT missed 3 additional intracardiac anomalies over and above those missed by Echo. This can be attributed to the fact that very small Atrial or Ventricular septal defects with compensated circulation may not produce pronounced secondary changes hence making MDCT to play a suboptimal role in its diagnosis because its identification is based more on these secondary changes. Echocardiography with colour Doppler can pick up these defects more easily as it is more sensitive in detecting velocity changes seen in small ASD or VSD.

MDCT was able to diagnose the extracardiac anomalies more clearly along with which it could comment upon the status of peripheral pulmonary arteries (atresia, stenosis, dilatation,) SVC, IVC and the simultaneous evaluation lung fields and viscera while echocardiography

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lagged behind drastically. Hence the evaluation of extracardiac anomalies by MDCT was far more superior compared to ECHO as it has poor acoustic window limitations.
From our study we found that while the diagnostic accuracy of ECHO and MDCT for Intracardiac anomalies goes hand in hand, the diagnostic accuracy of MDCT for extracardiac anomalies was superior to that of ECHO. The information obtained by ECHO is usually inadequate for pre-operative surgical planning of the patient. MDCT provides a more detailed analysis of the anomalies with clear delineation of the exact anatomical profile. This helps the surgeon to plan the surgery tailored accordingly to each patient as there is gross overlapping of anomalies in the spectrum of Congenital Cardiovascular Diseases.

Conclusion

Armed with this knowledge, we can diagnose congenital heart disease and evaluate the long-term outcome after surgical repair using Cardiac CT Angiography. MDCT provides accurate morphologic data, decreasing potential diagnostic errors and increasing diagnostic accuracy and confidence when the results of other cardiac imaging methods like Echocardiography are equivocal or nondiagnostic. Reformatted images from MDCT can accurately and systematically delineate the normal and pathologic morphologic features of the cardiovascular structures.

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