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CORRELATION OF MULTIDETECTOR COMPUTED TOMOGRAPHY AND TRANSTHORACIC ECHOCARDIOGRAPHY IN THE DIAGNOSIS OF CONGENITAL CYANOTIC HEART DISEASES

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Article Info

Abstract

Background: Congenital Cyanotic Heart Diseases (CCHDs) are among the most common birth defects in newborns, with Tetralogy of Fallot (TOF) being the most frequent type, affecting about three in every 10,000 live births.

Objective: This study aims to evaluate the diagnostic accuracy of echocardiography compared to multidetector computed tomography angiography (MDCTA) in diagnosing CCHDs.

Methodology: Conducted between June and October 2024 at Chughtai Lab and Health Care in Lahore, this descriptive cross-sectional study included 122 patients diagnosed with CCHDs using both echocardiography and MDCTA. Echocardiographic assessments were performed with a GE Vivid 7 ultrasonography system, while MDCT scans were carried out using Toshiba's Aquilion® system. Data analysis involved Pearson's correlation coefficient to compare the two imaging techniques.

Results: The study evaluated 122 participants with an average age of 68 months. The correlation analysis revealed strong agreements between echocardiography and MDCTA measurements, especially for cardiac morphology (Pearson correlation coefficient of 0.929, $p < 0.001$). Both imaging methods consistently identified atrial septal defect (ASD), ventricular septal defect (VSD), and double outlet right ventricle (DORV).

Conclusion: While MDCTA is highly accurate in visualizing extracardiac abnormalities, echocardiography remains the most effective tool for detecting intracardiac anomalies. Both methods are reliable for diagnosing structural heart defects in children with CCHDs.

Keywords: *Pediatric Cardiology, Congenital Cyanotic Heart Diseases, Echocardiography, Multidetector Computed Tomography Angiography*.

Introduction

Congenital Cyanotic Heart Diseases (CCHDs) remain one of the most prevalent abnormalities during birth in neonates. Tetralogy of Fallot (TOF) represents the common type of CCHDs, affecting around three out of every 10,000 live infants (1). Severe CCHDs frequently need surgery in the initial years of life, ideally between 3 to 6 months of age, to avoid heart tissue damage (myocardial fibrosis) and to treat the detrimental consequences of low oxygen levels (central cyanosis) in developing newborns. Early and appropriate assessments and treatments are essential for increasing infant chances of better life survival (2).

Echocardiography (echo) is the principal imaging technique for diagnosing CCHDs. This sophisticated tool gives comprehensive images of cardiac anatomy as well as information on blood flow and cardiac function (3, 4). Echo is extensively used because it is rapid, can be performed at the patient's bedside, focuses exclusively on the heart and big blood veins, does not utilize radiation, and aids in the early detection of problems. However, its limits include the operator's expertise and the inability to see blood arteries outside of the heart (5).

Multidetector-row computed tomography angiography (MDCTA) provides a noninvasive technique for the heart and coronary arteries imagining (6). Recent developments in MDCTA technology, such as enhanced hardware, software, and machine learning, have increased its application in imaging complicated CCHDs. MDCTA provides pictures with excellent resolution and comprehensive 3D reconstructions, which render extremely useful for displaying cardiac anatomy (7), especially when studying veins outside the heart and coronary arteries (8-11). It may often be used instead of echocardiography and cardiac catheterization (12-14).

Older CT scanners with continuous ECG-gated scans may expose CHD patients to significant radiation exposures (up to 28 mSv each scan). However, recent advances such as prospective ECG gating, controlled tube current modulation, high-pitch helical scans, decreased tube voltage, increased detector coverage, and iterative reconstruction have greatly reduced radiation exposure (2). Modern CT systems also acquire pictures swiftly, frequently without the need for sedation or anesthesia. Many scans may be completed in a single heartbeat using dual-source scanning and extensive detector coverage, with patients rarely having to hold their breath (15).

Methodology

This descriptive cross-sectional study took place between June and October 2024 within the Radiology department of Chughtai Lab and Health Care, Lahore by calculating sample size by using formula , n = [DEFF*Np(1-p)]/ [(d2/Z21-α/2*(N-1)+p*(1-p)] was used, where n was the sample size, Z was confidence level (95%) and ($Z\alpha/2$) =1.96, N was the Population size (1000), P was the proportion (10%) (16). The calculated sample size was 122 using Convenient sampling technique.

The inclusion criteria were those patients who were confirmed to CCHDs by TTE and MDCT, concentrating on patients younger than eighteen who were hospitalized to the intensive care unit and who had both 320-row MDCT angiography and echocardiography, where the exclusion criteria were patients with the previous cardiac surgery or any other interventional procedure was done in past before and with other comorbidities that affect cardiac functions. Informed consent was secured from all participants suspected of having congenital heart disease, while postoperative cases coming in for follow-up were excluded. Before the study began, institutional ethical and academic committee approval was acquired.

Utilizing a GE Vivid 7 ultrasonography system equipped with both 3-MHz and 6-MHz probes, echocardiographic evaluations were conducted. Various echocardiographic views were captured, including subcostal, parasternal, apical, and suprasternal perspectives. The study examined numerous essential factors, including atrial and Veno atrial situs, ventricular morphology, ventricular outflow, atrioventricular (A-V) connections, intracardiac wall abnormalities, great artery placement, and extracardiac vascular anomalies.

MDCT scans were performed utilizing Toshiba's Aquilion® system, which used a non-ECG gated protocol using a pitch factor of 3, a gantry rotation duration of 350 ms, and a temporal resolution of 175 ms. The z-axis CARE dose modulation technique was used to optimize the radiation dosage for each patient. Patients weighing less than 20 kg received 80 kV, while those from 20 to 80 kg received 100 kV. Patients weighing more than 9 kg received a tube current of 10 mA/kg, with an additional 5 mA for each kilogram (17-19).

Imaging data were collected during a manually administered intravenous injection of the contrast material (Omnipaque 300 mgI/ml) for infants or those under one year, whereas young children received 1-1.5 ml/kg of iohexol (KOPAQ®) at a rate of 1-3 ml/s. Depending on the child’s weight, 4–15 milliliters of saline were used to flush the contrast. A bolus tracking technique was utilized to determine the optimal scanning delay. All patients-maintained sinus rhythm, with heart rates surpassing 80 beats per minute, and none required beta-blockers. For uncooperative newborns and children, sedation was provided using midazolam or ketamine. All MDCT acquisitions were performed while patients breathed freely.

The images were reconstructed with a 25f kernel filter to a thickness of 0.6 mm. Multiplanar reformats, maximum-intensity projections, and volume renderings were managed using workstation called Vitrea, Vital Images Inc. Radiologists and pediatric cardiac doctors with over ten years of expertise in cardiovascular imaging independently evaluated the echocardiography and MDCTA pictures, and findings were agreed upon.

The data was input and analyzed using Microsoft Excel 365 and SPSS version 27. The patient's demographics have been analyzed using central tendency measures (mean and median). Pearson's correlation coefficient was used to analyze the relationships between MDCTA and TTE readings., with a significance level set at $p < 0.05$.

Results

In this study, 122 participants diagnosed with CCHDs were evaluated, with an overall mean age of approximately 68 months (about 5.7 years) and a standard deviation of 80.57 months, reflecting a wide range of ages. Participants’ ages varied from as young as 1 month to as old as 216 months (18 years). Among the participants, 89 were male, with an average age of about 61 months (around 5.1 years) and a standard deviation of 78.33 months, indicating significant age variability within the male group. Ages for male participants ranged from 1 month to 18 years, covering the entire age span of the study. In contrast, the 33 female participants had a mean age of roughly 87 months (about 7.3 years), with a standard deviation of 84.52 months, and an age range from 3 months to 204 months (17 years). This data highlights the diversity in age and gender among participants, with a tendency for female participants to be slightly older on average than male participants.

Variable	Observations	Mean	Std. Dev.	Min	Max
Age (months)	122	68.13	80.57	1 month	216 months (18 years)
Male	89	61.00	78.33	1 month	216 months (18 years)
Female	33	87.36	84.52	3 months	204 months (17 years)

The correlation analysis between measurements obtained via echocardiography and MCTA demonstrates strong agreements across different variables. For right ventricular outflow tract obstruction, the Pearson correlation coefficient is 0.898, with a significance level of <0.001, indicating a robust positive correlation. This suggests that echocardiography and MDCTA produce highly consistent measurements for this condition. Similarly, the correlation for peripheral artery disease between echocardiography and MDCTA is also strong, with a coefficient of 0.815 and the same significance level, pointing to substantial alignment between the two methods, although this correlation is slightly lower than for the other variables. Cardiac morphology exhibits the highest correlation, with a coefficient of 0.929 and a significance level of <0.001, indicating an excellent agreement between echocardiography and MDCTA assessments. These findings suggest that both methods yield consistent results, particularly for cardiac morphology, and could be used interchangeably for clinical assessments.

Variables (Echo vs MDCTA)	Pearson Correlation	Significance (2-tailed)	Observations
Right ventricular outflow tract Obstruction	0.898**	< 0.001	122
Peripheral artery disease	0.815**		
Cardiac Morphology	0.929**		

Correlation is significant at the 0.01 level (2-tailed).

Additionally, both Echocardiography and MDCTA consistently detected Atrial Septal Defect (ASD) and Ventricular Septal Defect (VSD) in patients, with positive findings across both imaging methods. Additionally, Double Outlet Right Ventricle (DORV) was identified equally well by both echocardiography and MDCTA, indicating that the two modalities are comparable in their ability to diagnose these specific heart abnormalities. These results underscore the reliability of echocardiography and MDCTA as diagnostic tools for assessing structural heart defects like ASD, VSD, and DORV, suggesting that either modality can be effectively used in clinical settings for these conditions.

Discussion

This study evaluated the effectiveness of echocardiography and multidetector computed tomography angiography (MDCTA) in predicting surgical outcomes for patients with CCHDs. Both imaging techniques demonstrated high sensitivity and specificity in identifying anatomical details procedures. Additionally, MDCT proved to be a valuable complementary tool alongside echocardiography for evaluating extracardiac vascular structures.

Children with CCHDs present in the emergency department (ED) in a variety of ways: in shock, cardiac failure, or for the first time for murmur evaluation, or for the management of spells or chest infections, or for a problem following cardiac surgery. As a result, any kid who appears in critical condition to the ED should be suspected of having heart disease and extensively examined for CCHDs, as advised by Bano et al. (20).

Echocardiography has long been the go-to imaging technique for evaluating cardiac function, anatomical anomalies, and hemodynamic status in pediatric patients. Its popularity stems from its cost-effectiveness, portability, wide availability, and the fact that it doesn't involve radiation exposure. For children with complex congenital heart diseases (CCHDs), echocardiography is especially crucial for assessing cardiac morphology before, during, and after both surgical and conventional angiographic procedures.

In recent years, various research have focused on CCHDs, in the previous literature studies, it states that echo cardiography has high sensitivity and specify taking gold standard surgery or conventional interventional procedures. Rakha et al. (21) concluded in their study that echocardiography found a sensitivity of 97.03%, specificity of 99.07%, and accuracy of 98.47% for fetal. As same study was conducted by Chu et al. (22) results demonstrated high sensitivity and specificity for detecting major CHDs in both low-risk and high-risk populations, with sensitivity rates of 88.2% and 100%, respectively. However, the detection rates for minor CHDs were significantly lower. The study concluded that incorporating detailed fetal echocardiography with multiple cardiac views into routine ultrasound screening could improve the detection of major CHDs, thereby facilitating better parental counseling and decision-making.

While MDCTA has its limitations, such as the absence of hemodynamic data, exposure to ionizing radiation, and challenges with contrast materials, technological advancements have significantly improved its use and diagnostic accuracy in children with congenital heart disease (CHD) (23, 24). The latest generation of multidetector computed tomography angiography (MDCTA) is proving to be increasingly valuable in assessing children with complex CHD. Its key advantages include precise identification of anatomical details, the ability to conduct three-dimensional assessments, and the requirement for small volumes of contrast material to visualize vascular structures effectively. MDCTA also enhances the visualization of coronary arteries and their branches while allowing for the examination of non-cardiac structures. The scanning process is quick, typically taking just a few seconds, and it generally involves lower radiation exposure compared to traditional methods. Furthermore, various studies have indicated that MDCTA significantly lessens the reliance on diagnostic cardiac catheterization and angiography, previously regarded as the gold standard for CHD diagnosis (25-28).

Our study was limited by being conducted at a single center with a small patient sample. A larger cohort would likely yield more accurate results in terms of sensitivity and specificity. Additionally, the complex and varied nature of congenital heart disease (CHD) patients posed classification challenges that may have impacted our outcomes. To reduce errors and misdiagnoses, experienced pediatric cardiologists and radiologists meticulously reviewed all examinations.

Conclusion

In conclusion, our findings indicate that while MDCTA excels in visualizing extracardiac abnormalities with high accuracy and echocardiography proves to be the most effective modality for intracardiac anomalies.

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