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Role of Cardiac CT in Evaluating Vascular versus Cardiac Congenital Heart Diseases in Children

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Abstract

Background: CHD is the most common birth anomaly worldwide and it has a significantly increasing prevalence rate. Traditional evaluation for assessment depends on ECHO and conventional angiography. Recent technological advances in MDCT, is increasingly used for non-invasive evaluation. The aim of this study was to evaluate the value of MDCT in assessment of vascular and cardiac CHD in pediatrics as a non-invasive preoperative planning method and to compare its results with those of ECHO.

Aim of Study: To assess the role of cardiac CT in the evaluation vascular versus cardiac congenital heart diseases in children.

Material and Methods: This single center prospective study included 50 children up to 12 years-old from both sexes with a clinical suspicion to have CHD and referred to perform ECHO and then MDCT examination for further evaluation before surgery. The study was conducted in radiology department Fayoom University, after referral from the pediatric cardiology clinic.

Results: This study included 50 children, whom are known to have CHD by ECHO and referred to perform MDCT examination for further evaluation before surgery. Among the 50 children in the study; we encountered 273 anomalies in total, which further specified into 23 different types of CHD. The diagnostic sensitivity, specificity, KAPPA and *p*-values for both ECHO and MDCT, and ROC was performed according to AUC values of 2 methods.

We compared sensitivity and specificity for ECHO and MDCT in the diagnosis of different congenital cardiovascular malformations with higher sensitivity of about 100% for ECHO in the detection of cardiac structure and heart-vascular connection malformations, but higher sensitivity for MDCT of about 100% for detection of vascular malformations. For cardiac structures malformation, both ECHO and MDCT are considered as good positive, but bad negative tests with sensitivity more than 92%, but specificity only 50%. The AUC value of ECHO was slightly larger than that of MDCT for cardiac structures malformations (75% vs. 71.4%) and for heart-vascular connection malformation (100% vs. 98.6%), but slightly smaller for ECHO than that of MDCT for vascular malformations (96.6% vs. 100%). The KAPPA value of ECHO was also slightly larger than that of MDCT for cardiac structures malformations (0.627 vs. 0.45) and for heart-vascular connection malformation and (1 vs. 0.951), but much smaller than that of MDCT for vascular malformations (0.545 vs. 1).

Conclusions: The diagnostic sensitivity of both MDCT and ECHO for CHD is generally high with slightly higher sensitivity for ECHO. Each has its own advantages and disadvantages. Overall ECHO is better than MDCT in the diagnosis of the cardiac structures anomalies, especially for atrial septal anomalies as PFO, ASD and ASA. Both are accurate in the diagnosis of heart-vascular malformations, including: DORV and TGA. On the other hand, MDCT provides higher sensitivity in the anatomic structural details for vascular malformations, Aortic pseudo-coarctation, Aortic arch anomalies, peripheral pulmonary stenosis, abnormal systemic venous drainage and tracing of MAPCAs. Thus, we recommend ECHO in the diagnosis of cardiac structures malformations, whereas MDCT is better for vascular malformations.

Key Words: *MDCT – ECHO – Cardiac – Complex – CHD – Pediatrics.*

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Introduction

CONGENITAL heart disease (CHD) is the most common type of congenital malformation with an incidence of 0.8% among newborns. It was reported that the primary cause of mortality in newborns was related to the abnormal structure or function of the heart. CHD has a great negative effect on the growth and development of children. Early diagnosis is crucial for treatment and prognosis **[1]**.

Imaging is important in the pre and postoperative management of patients with CHD. From the fetal stage onward, imaging outlines anatomy and physiology, helps to refine management, evaluates the consequences of interventions, guides further procedures and provides prognostic information in this unique set of patients **[2]**.

Cross-sectional imaging has become a crucial component in the diagnostic pathway in patients with CHD over the last decade. Their use compliments echocardiography (ECHO) and, for many cases, has superseded the use of diagnostic cardiac catheterization. Although cardiovascular magnetic resonance imaging (CMR) is still the main form of cross-sectional imaging for CHD, increases in the speed of the computed tomography (CT) and reductions in the radiation dose (sub-mSv radiation dose exposure), rendered cardiovascular CT increasingly used for the assessment of CHD, in particular in neonates and young children **[2]**.

Cardiac CT has proven to be a very useful imaging modality for patients with CHD. The high spatial resolution allows viewing in multiple two-dimensional or curvilinear planes, along with the ability for excellent three-dimensional reconstructions. This inherent three-dimensional property of cardiac CT makes it useful for imaging tortuous vessels and defining complex anatomical relationships. With a scan time of only a few seconds or less, it is possible to image most children without sedation. Rapid image acquisition with current CT scanners results in minimal motion artifacts from breathing and poor cooperation **[3]**.

ECHO is likely the first choice to screen a patient for suspected CHD, valvular disease, heart failure and pericardial abnormalities. It is easily accessible and effective in many patients. However, suboptimal acoustic windows may prevent from reaching a conclusive diagnosis. The right heart is challenging due to its retrosternal position, the left atrial appendage (LAA) is faintly seen with transthoracic approach and the contents of the pericardium can look rather ominous. The assessment of regional myocardial function and the quantification of chamber volumes and systolic function are known to be operator dependent. Lastly, ECHO has difficulties to visualize the coronaries in details **[4]**.

Unlike ECHO, cardiac CT is window independent, has a large field of view (FOV) and provides excellent visualization of airway structures and coronaries. In contrast to MRI, CT imaging is less likely to require sedation or anesthesia and is minimally affected by metallic devices, such as stents, coils, pacemakers and defibrillators **[4]**.

Patients and Methods

This single center prospective study was conducted in Fayoom University Hospital between April 2020 to June 2021 and included 50 children up to 12 years-old from both sexes with a clinical suspicion to have CHD and referredto perform ECHO and then MDCT examination for further evaluation before surgery. The study was conducted in radiology department after referral from the pediatric cardiology clinic.

Inclusion criteria included Children with CHD whom ECHO findings are not sufficient and referred to perform MDCT for further evaluation.

Exclusion criteria was Hypersensitivity to iodinated contrast media, impaired renal function, respiratory distress, fever and patients who had non-sinus rhythm.

All Patients were submitted to full history taking with reviewing of previously performed imaging in patients who are on follow-up and clinical assessment of the patients, in the form of measuring of vital signs and anthropometric measurements, including: Weight, height and percentiles.

ECHO Performance: ECHO examination was performed using Vivid S5 GE Cardiac-Vascular Ultrasound Machine. Cardiac functions were measured using multiple imaging modalities, such as 2D ECHO with color Doppler imaging and conventional B-mode ECHO. ECHO often started with subcostal, preceded to apical, right, left parasternal and suprasternal acoustic windows with the major cardiovascular structures were assessed according to Van Praaghsegmental analysis. Referral from ECHO to MDCT was based on a wide range of indications, especially for assessment of the pulmonary arterial tree, Aortic arch and descending Aorta, coronary arteries, anomalous pulmonary, systemic venous drainage malformations and tracing of MAPCAs.

Patient preparation for MDCT:

We started by measuring of child's body weight for calculation of amount of contrast media and sedative material if indicated. The patient should be fasting for 4 hours with checking of his serum creatinine before contrast administration. A peripheral venous line is inserted usually in a right upper limb vein. Children who were below 6 years-old and uncooperative were orally administered 10% chloral hydrate at a dose of 50mg/kg, 30min before MDCT scanning. Children aged 6 years or older underwent the study without need of sedation.

The child lie in a supine position and at the middle of CT gantry. ECG leads were put on the chest of the patient. Patients were scanned using 160 MSCT Toshiba Aquilion Prime, Toshiba medical systems, Japan.

The radiation dose was kept to minimum by reducing the kilo voltage to 80-100kvp and tube current was adjusted during acquisition according to body weight to range from 10 to 40mA/kg. The gantry speed was set at a 0.35-s rotation with a helical thickness of 0.5mm and detector coverage of 32mm. Pitch of 1.3. Prospective cardiac gating was frequently used, and radiation dose was estimated for retrospective ECG-gated scanning to be around 3-5mSv. Nonionic contrast agent (Omnipaque 350mg/mL) was injected using dual-phase injection protocol through a peripheral venous line by using a power injection followed by the same volume of saline with an injection rate of 1-1.5mL /s. The total contrast volume used for pediatric CT is typically 1.5-3ml/kg. Scanning begins when contrast filled the LV. The patient was scanned in a cranio-caudal direction starting at the level of the subclavian artery and ending at the level of the diaphragm. Another caudo-cranial scanning study for full coverage of arterial and venous vasculature. We acquired images either by bolus tracking or manual. The scan may be manually triggered on the basis of the visual estimate of optimal contrast in the ROI on a monitoring sequence. Examination of the heart was then performed. Sequential series of images in arterial and subsequent phase of enhancement were taken to ensure opacification of both sides of the heart and all extra-cardiac vessels. All reconstructed images were transferred to a dedicated workstation. Multi-planner reformation (MPR), maximum-intensity projection (MIP) and volume-rendering technique (VRT) were performed for images interpretation.

Statistical analysis:

Data were collected and coded to facilitate data manipulation and double entered into Microsoft Access and data analysis was performed using the Statistical Package of Social Science (SPSS) software version 22 in windows 7. Simple descriptive analysis in the form of numbers and percentages of qualitative data, arithmetic means as central tendency measurement and standard deviations (SD) as a measure of dispersion of quantitative parametric data.

For quantitative data: Independent samples *t*-test: Was used to compare quantitative measures between two independent groups.

For qualitative data: Chi-square test: To compare two or more than two qualitative groups.

- KAPPA value: To detect the accuracy of 2 methods using paired dependent qualitative data.
- Sensitivity and specificity tests and then analysis was conducted to compare diagnostic area under the ROC curve "Receiver Operating Characteristic" according to AUC value of 2 methods.
- The p-value <0.05 was considered of a statistical significance.

Results

In the current study, we recruited 50 children at the Radiology Department, during the time period from October 2019 to April 2020. These patients were aged from 0 day to 12 years-old from both sexes, who are known to have CHD by ECHO and submitted for further evaluation by MDCT, usually before surgery.

We included 30 females and 20 males in this study. The mean age of the study group was 25.8 ±44.8 months-old ranging from 0 to 144 months-old. As regards vital signs, the mean heart rate was 111±18 beats per minute, which ranged from 70 to 140 beats per minute. Finally, the mean blood pressure was 67±8.4mmHg, which ranged between 56 and 87mmHg.

Table (1) illustrated that 80% of cases were symptomatic, while 58% complained chest troubles, 42% had cyanosis and 42% showed delayed milestones.

Sedation was needed during MDCT performance in 34 patients corresponding to 68% of the study subjects.

Table (2) illustrated that there was a statistically significant difference between ECHO and MDCT in the diagnosis of PFO, as ECHO is more accurate with p-value <0.05. There was no statistically significant difference between ECHO and MDCT in the diagnosis of other cardiac structures malformations with p-value >0.05, which indicated that both ECHO and MDCT could detect cardiac structures malformations other than PFO in the same accuracy.

Regarding the cardiac structures malformations with a statistically significant difference between ECHO and MDCT in in this study with p-value <0.05, we found that 24% of patients in this study had PFO in association with other anomalies. Only 2% were under diagnosed by ECHO, due to insignificant results variations in size, while 12% were mis-diagnosed and not visualized by MDCT (Fig. 1).

Table (3) illustrated that there was no statistically significant difference between ECHO and MDCT in the diagnosis of heart-vascular connection malformations, including: DORV, TGA, Aortic and pulmonic valves malformations with p-value

>0.05 in all of these parts, which indicated that both could detect these malformations in the same accuracy. However, the lowest *p*-value in heart-vascular connection malformations was for PV malformations (Fig. 1).

Table (4) illustrated that there was a statistically significant difference between ECHO and MDCT in the diagnosis of most of vascular structures malformations, especially for Aortic pseudo-coarctation, Aortic arch anomalies, peripheral pulmonary stenosis, abnormal systemic venous drainage (Fig. 5), coronary arteries anomalies and MAPCAs with *p*-value <0.05 for each of these parts. The smallest *p*-value in vascular structures malformations was for MAPCAs of 0.06. Thus, this study revealed that MDCT is more accurate than ECHO in the diagnosis of these malformations (Fig. 1).

On the other hand, there was no statistically significant difference between ECHO and MDCT in the diagnosis of vascular malformations other than the fore mentioned ones, including: Aortic coarctation, PAH, PDA, Abnormal pulmonary venous drainage with *p*-value >0.05 in these parts, meaning that, both ECHO and MDCT can detect these anomalies by the same accuracy (Fig. 2).

Regarding each type of vascular malformations, which showed a statistically significant difference between ECHO and MDCT in this study with *p*-value <0.05, we found that 18% of patients had Aortic pseudo-coarctation, proved by the kinking appearance of the Aorta with no collaterals detected in MDCT. All of them were discovered by MDCT, while errors occurred by ECHO, as 4% of cases were falsely diagnosed as Aortic coarctation, while 2% of cases were suspected and referred to MDCT for further evaluation (Fig. 3).

18% of patients in this study had different types of Aortic arch anomalies, including: Double aortic arch, right-sided Aortic arch, aberrant right subclavian artery, abnormal vertebral artery origin from the Aortic arch and Aortic arch hypoplasia. Also, all of them were discovered by MDCT, while ECHO missed 16% (Fig. 4).

40% of patients in the study had peripheral pulmonary stenosis at different levels. All of these anomalies were discovered by MDCT. No MDCT peripheral pulmonary stenosis under or mis-diagnoses. By ECHO, only 18% were discovered, while 10% were suspected and 12% were missed.

We found 20% of patients among the study, who had different types of abnormal systemic venous drainage, including: PLSVC, interrupted IVC, double IVC and retro-Aortic innominate vein. All of them were discovered by MDCT. By ECHO, only 8% were discovered, while the largest percentage as for missed cases of 12% (Fig. 2).

Throughout this study, there were 8% of patients who had coronary arteries anomalies, including: Coronary artery fistulae, aneurysms and abnormal coronaries origin. All were discovered by MDCT, while errors occurred by ECHO. 6% of cases missed by ECHO and 2% of cases were suspected (Fig. 6).

Among study group, we found that 28% of patients had MAPCAs (Fig. 7), whom totally discovered by MDCT. By ECHO, only 8% were discovered, 10% were under diagnosed as we needed further evaluation of MAPCAs with significant different data obtained by MDCT in these cases. 10% of cases were missed by ECHO.

Table (5) showed results of sensitivity and specificity tests for both ECHO and MDCT in the diagnosis of different types of CHD throughout the current study with higher sensitivity of 100% for ECHO in the detection of cardiac structures and heart vascular connection malformations, while higher sensitivity for MDCT of about 100% inthe diagnosis of vascular malformations.

For cardiac structures malformation, both ECHO and MDCT are considered as good positive, but relatively bad negative tests with sensitivity higher than 92.9% and specificity only 50% for both modalities.

The AUC value of ECHO was slightly larger than that of MDCT for cardiac structures malformations (75% vs. 71.4%), as well as for heart-vascular connection malformations (100% vs. 98.6%), but AUC value of ECHO was slightly smaller than that of MDCT for vascular malformations (96.6% vs. 100%).

The KAPPA value of ECHO was also slightly larger than that of MDCT for cardiac structures malformations (0.627 vs. 0.45), as well as for heart-vascular connection malformations (1 vs. 0.951), but much smaller than that of MDCT for vascular malformations (0.545 vs. 1).

In the final analysis, as seen in Table (6), the diagnostic sensitivity of ECHO and MDCT was 97.93% and 96.7%, respectively, while the diagnostic specificity was 83.3% for both. The results of comparison between ECHO and MDCT revealed that there was no statistically significant difference in the diagnostic accuracy between the 2 methods with KAPPA=0.762 and *p*-value=0.3.

Table (1): Frequency of different symptoms among study group.

Variables (n=50)	Symptoms	
	Number	%
Symptomatic	40	80
Asymptomatic	10	20
No chest troubles	21	42
With chest troubles	29	58
Non-cyanotic	29	58
Cyanotic	21	42
Normal milestones	29	58
Delayed milestones	21	42

Table (2): Comparison between ECHO and MDCT in the diagnosis of cardiac structures malformations.

Cardiac structures malformations	Diagnostic modality	(No., %) of findings (n=50)			*p*-value
		Mis-diagnosis	Under diagnosis	Disc-overed	
ASD	ECHO	0 (0%)	0 (0%)	22 (44%)	0.1
	MDCT	3 (6%)	3 (6%)	16 (32%)	
PFO	ECHO	0 (0%)	1 (2%)	11 (22%)	**0.02***
	MDCT	6 (12%)	3 (6%)	3 (6%)	
ASA	ECHO	0 (0%)	0 (0%)	3 (6%)	0.09
	MDCT	0 (0%)	3 (6%)	0 (0%)	
VSD	ECHO	0 (0%)	0 (0%)	31 (62%)	1
	MDCT	0 (0%)	0 (0%)	31 (62%)	
Single atrium	ECHO	0 (0%)	0 (0%)	2 (4%)	1
	MDCT	0 (0%)	0 (0%)	2 (4%)	
Single ventricle	ECHO	0 (0%)	0 (0%)	5 (10%)	0.5
	MDCT	0 (0%)	2 (4%)	3 (6%)	
RVOTO	ECHO	0 (0%)	0 (0%)	17 (34%)	0.7
	MDCT	3 (6%)	0 (0%)	14 (28%)	
TV malformation	ECHO	0 (0%)	1 (2%)	5 (10%)	0.3
	MDCT	2 (4%)	2 (4%)	2 (4%)	
MV malformation	ECHO	0 (0%)	0 (0%)	6 (12%)	0.3
	MDCT	2 (4%)	1 (2%)	3 (6%)	

*: A statistically significant value.

Table (3): Comparison between C ECHO and MDCT in the diagnosis of Vascular Malformations.

Heart-vascular connection malformations	Diagnostic modality	(No., %) of case findings (n=50)			*p*-value
		Mis-diagnosis	Under diagnosis	Disc-overed	
DORV	ECHO	0 (0%)	0 (0%)	8 (16%)	0.3
	MDCT	0 (0%)	2 (4%)	6 (12%)	
PV malformations	ECHO	0 (0%)	0 (0%)	34 (68%)	0.06
	MDCT	2 (4%)	2 (4%)	30 (30%)	
Aortic valve malformations	ECHO	1 (2%)	0 (0%)	3 (6%)	0.9
	MDCT	1 (2%)	0 (0%)	3 (6%)	
TGA	ECHO	0 (0%)	0 (0%)	7 (14%)	0.3
	MDCT	0 (0%)	1 (2%)	6 (12%)	

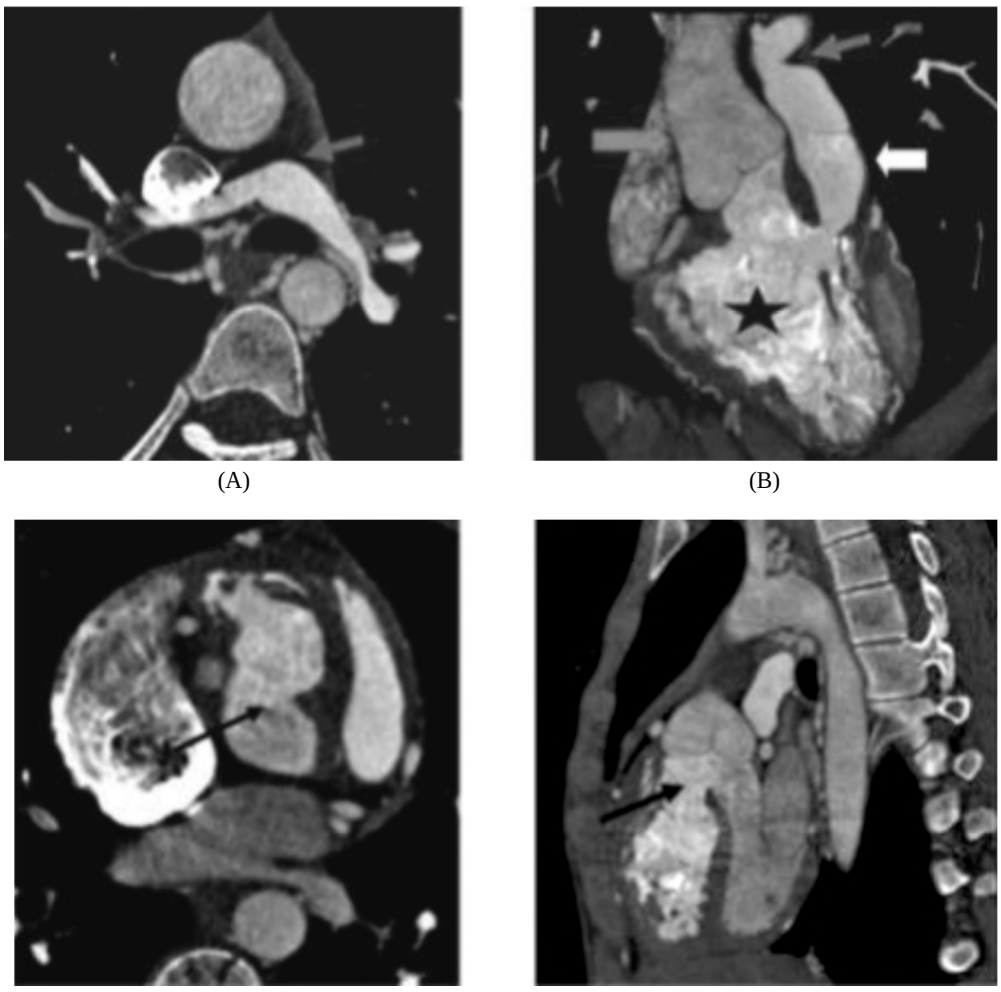
Table (4): Comparison between ECHO and MDCT in the diagnosis of vascular malformations.

Vascular malformations	Diagnostic modality	(No., %) of case findings (n=50)			*p*-value
		Mis-diagnosis	Under diagnosis	Disc-overed	
Aortic pseudocoarctation	ECHO	2 (4%)	1 (2%)	0 (0%)	**0.04***
	MDCT	0 (0%)	0 (0%)	3 (6%)	
Aortic coarctation	ECHO	0 (0%)	4 (8%)	4 (8%)	0.4
	MDCT	0 (0%)	1 (2%)	7 (14%)	
Aortic arch anomalies	ECHO	8 (16%)	0 (0%)	1 (2%)	**0.01***
	MDCT	0 (0%)	0 (0%)	9 (18%)	
PA dilatation	ECHO	0 (0%)	2 (4%)	17 (34%)	0.3
	MDCT	0 (0%)	0 (0%)	18 (36%)	
Peripheral pulmonary stenosis	ECHO	6 (12%)	5 (10%)	9 (18%)	**0.03***
	MDCT	0 (0%)	0 (0%)	20 (40%)	
PDA	ECHO	1 (2%)	3 (6%)	20 (40%)	0.06
	MDCT	3 (6%)	3 (6%)	18 (36%)	
Abnormal pulmonary venous drainage	ECHO	1 (2%)	1 (2%)	3 (6%)	0.2
	MDCT	0 (0%)	1 (2%)	4 (8%)	
Abnormal systemic venous drainage	ECHO	6 (12%)	0 (0%)	4 (8%)	**0.03***
	MDCT	0 (0%)	0 (0%)	10 (20%)	
Coronary arteries anomalies	ECHO	3 (6%)	1 (2%)	0 (0%)	**0.01***
	MDCT	0 (0%)	0 (0%)	4 (8%)	
MAPCAs	ECHO	5 (10%)	4 (8%)	5 (10%)	**0.005***
	MDCT	0 (0%)	0 (0%)	14 (28%)	

*: A statistically significant value.

Table (5): Comparison between ECHO and MDCT in the diagnosis of CHD in details.

Variable	Sens-itivity	Spec-ificity	Positive predictive value	Negative predictive value	AUC	KAPPA
Cardiac structures malformations:						
ECHO	100%	50%	91.3%	100%	75%	0.627
MDCT	92.9%	50%	90.7%	57.1%	71.4%	0.45
Heart-vascular connection malformations:						
ECHO	100%	100%	100%	100%	100%	1
MDCT	97.2%	100%	100%	93.3%	98.6%	0.951
Vascular malformations:						
ECHO	93.8%	100%	100%	40%	96.9%	0.545
MDCT	100%	100%	100%	100%	100%	1

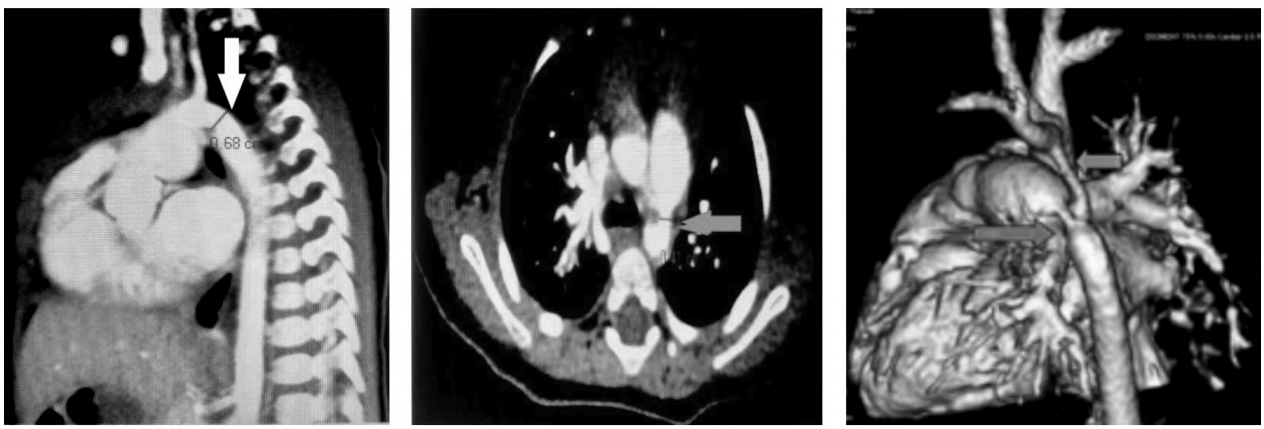


(A) (B)

(C) (D)

Fig. (1): A two months-old male child with a history of recurrent pneumonia. (A) Axial CT image showing MPA hypoplasia (green arrow). (B) Coronal reconstruction showing DORV. The RV (black asterisk) is dilated and hypertrophied. The exit of the Aorta is shown (red arrow) and the pulmonary trunk (white arrow) with main pulmonary artery hypoplasia (green arrow). (C) Axial image. (D) Sagittal reconstruction image showing the site of VSD (black arrow) and over-riding of Aorta.

• A six months-old female presented with tachypnea.



(A) (B) (C)

Fig. (2): (A) sagittal reconstruction CT images showing the site of isthmic narrowing (whitearrow), (B) Axial CT image showing the site of PDA trunk (blue arrow), (C) 3D reconstructed image showing the site of PDA (yellow arrow) and narrow segment of coarctation (light blue arrow).

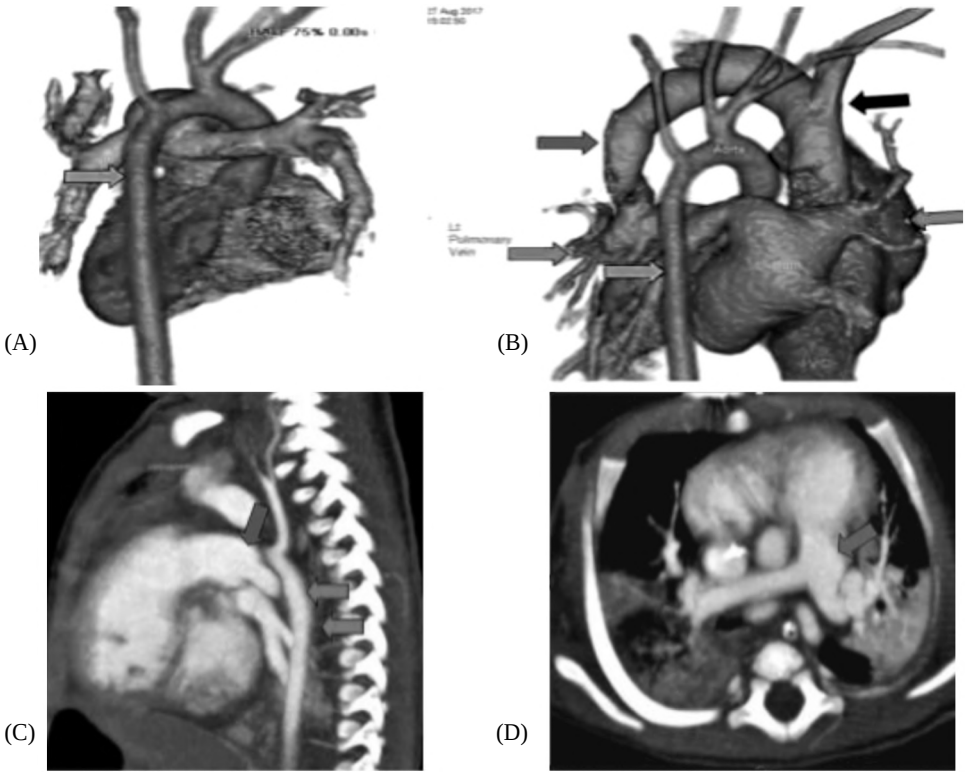


Fig. (3): (A,B) 3D reformatted images showing hypoplastic descending Aorta (yellow arrows) and Left superior pulmonary vein (light blue arrow) draining into PLSVC (green arrow). Right atrium is labeled by (red arrow) and SVC labeled by (black arrow). (C) Sagittal reconstructed CT image. (D) Axial MDCT image showing hypoplastic descending Aorta (red arrows) and congested and dilated main pulmonary artery (green arrows).

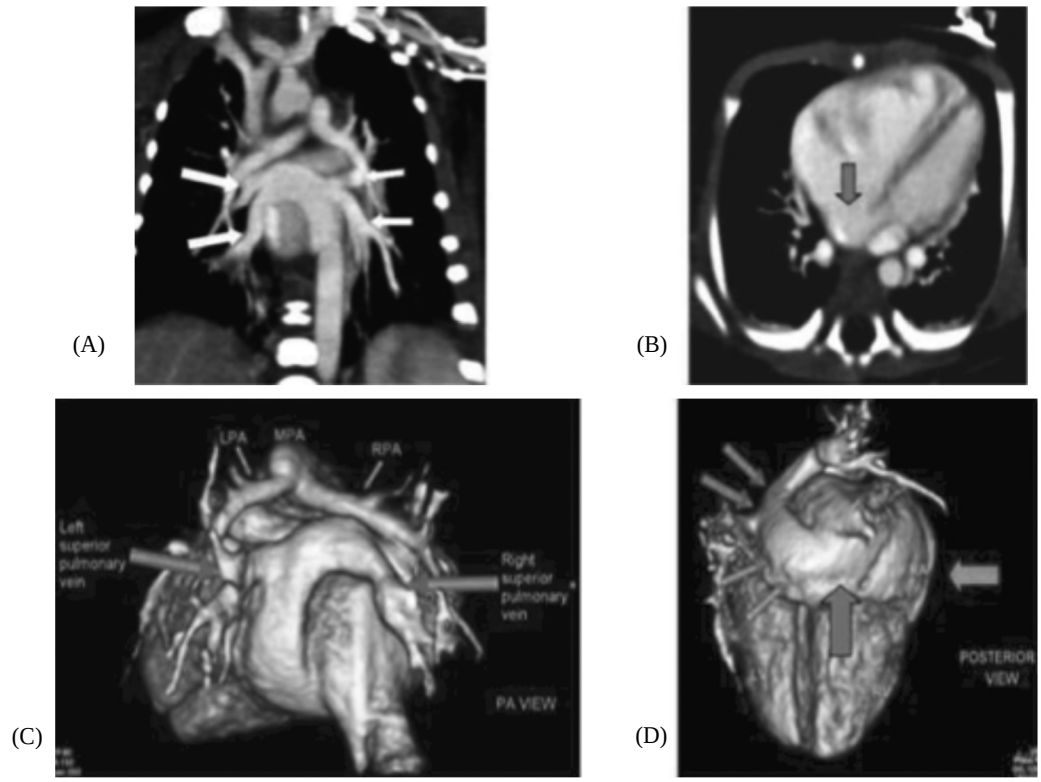


Fig. (4): (A) coronal reconstructed CT image showing the four pulmonary veins (white arrows). (B) Axial MDCT image showing large ASD (arrow). (C) 3D reformatted image showing the right and left superior pulmonary veins draining into the single vertical vein. (D) 3D reformatted image showing the vertical vein (four arrows), which drains pulmonary veins into dilated coronary sinus (arrow) to right atrium (arrow).

• A four months-old female child presented with bad general conditions and cryingsince birth.

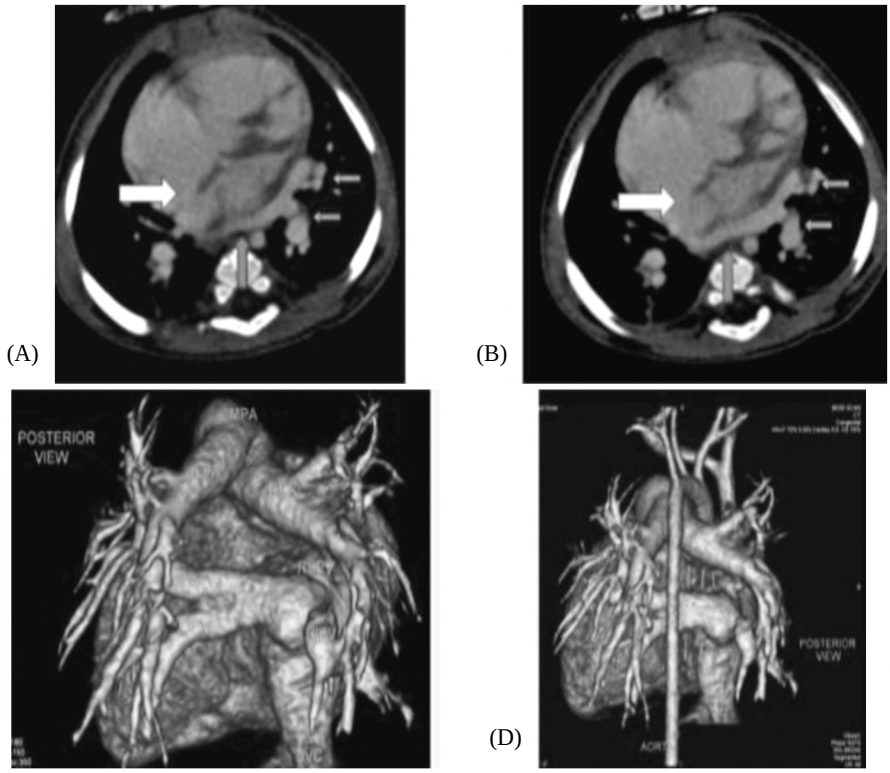


Fig. (5): (A,B) Axial sequential MDCT images showing dilated RA with ASD (white arrow), two left pulmonary veins (arrows) are draining into asingle vertical vein (arrow). (C,D) 3D reconstruction images, posterior view of heart and great vessels showing four pulmonary veins (asterisks) draining into single vertical vein (asterisks). Also, MPA and its right and left branches are seen dilated (arrow image C).

• A seven years-old male patient complaining of chest pain and dyspnea.

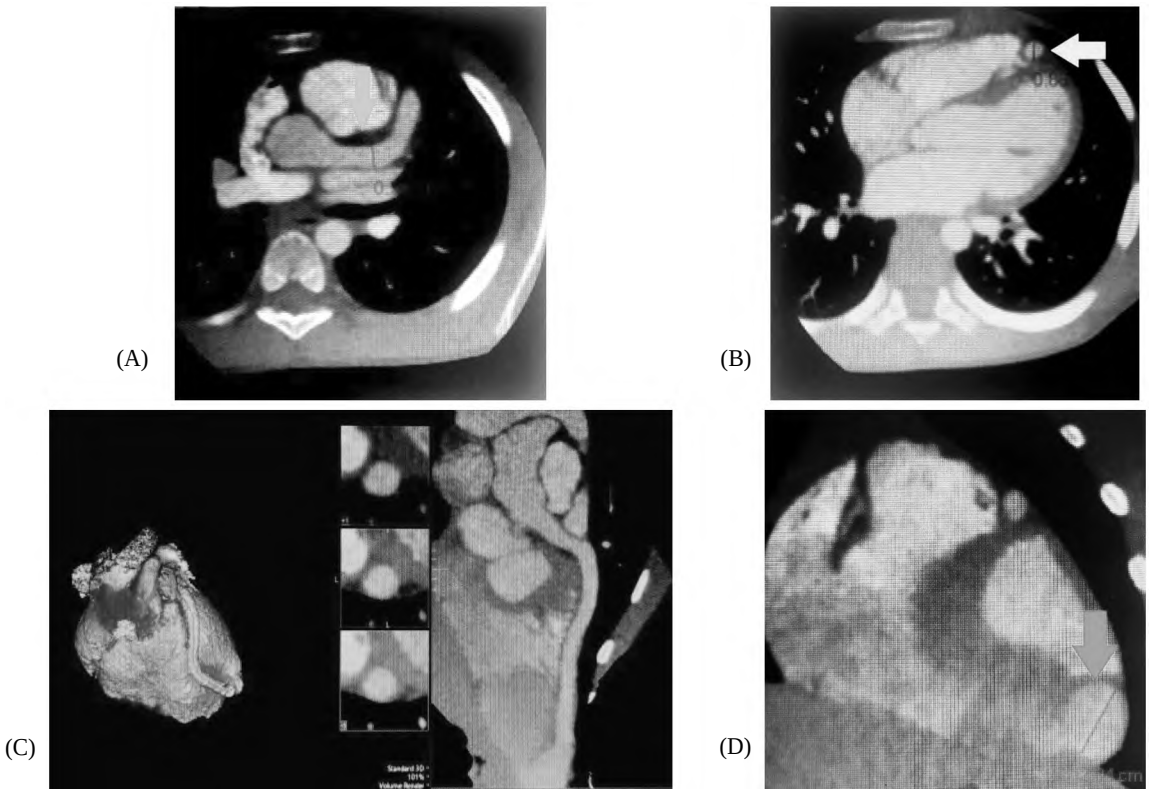


Fig. (6): (A,B) Axial CT images showing dilated LCA (red arrow) and LAD (white arrow). (C) 3D volume-rendering and oblique MPR images displaying dilated tortuous LAD ending by forming large aneurysm measuring about (30 x 20 mm) at maximal dimensions, as shown in (D) which shows LAD joining the right ventricular apex via an abnormal fistulous communication measuring about (9 mm) in width, thus creating left-to-right shunting of blood.

• A Thirteen months-old male child known to have complex CHD.

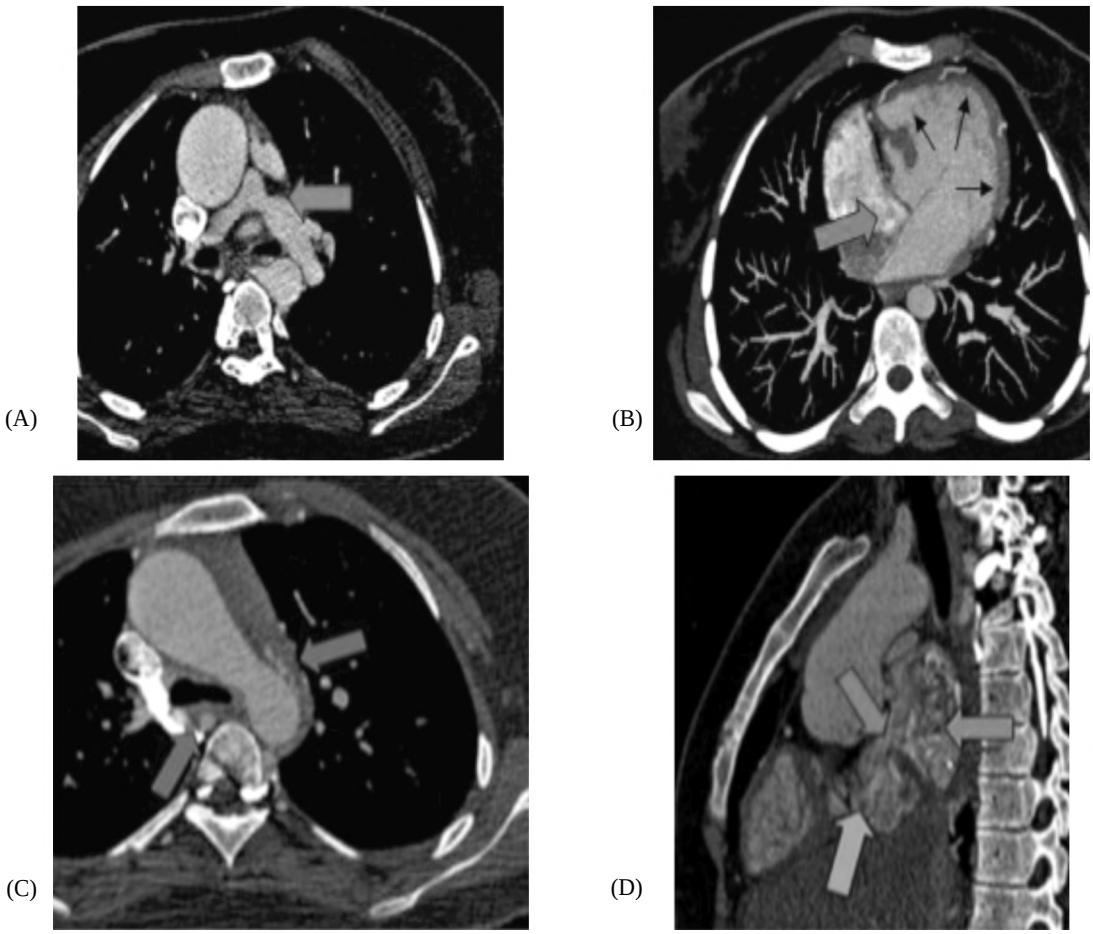


Fig. (7): (A) Axial MDCT images showing main pulmonary trunk and brancheshypoplasia (white arrow). (B) Axial image showing TV atresia (arrow) and single left ventricle (small black arrows). (C) Multiple MAPCAs (arrows). (D) Sagittal reconstructed CT image showing ASD (red arrow) between the RA (arrow) and LA (arrow).

Discussion

Among congenital diseases in infants and young children, CHD is considered common with complex CHD accounting for around 50% of the cases. Accurate and comprehensive preoperative evaluation of complex CHD is critical for selection of the appropriate surgical approach and prognostic evaluation **[5]**.

Advances in medical and surgical care of patients with CHD have resulted in expected survival for even the most complex lesions. Preoperative diagnostic evaluation is important. Also, patients with repaired or palliated CHD require serial diagnostic evaluations throughout their lives **[6]**.

The presence of ECHO in the 1970s led to a revolution in the non-invasive diagnosis of CHD with the advantages of non-invasiveness, speed, safety, ease of use, low-cost and widespread availability. ECHO is used to be the first line imaging modality for diagnosis and follow-up of neonates with CHD, minimizing the need for diagnostic cardiac catheterization and angiography **[7]**.

In the last two decades, MDCT scan emerged as a worthy non-invasive cardiovascular diagnostic tool efficient in providing accurate anatomic information not obtainable by other imaging modalities currently available **[8]**.

The improved spatial and temporal resolution, rapid image acquisition and radiation dose reduction of newer generation scanners have dramatically increased the applicability of MDCT scanning to patients with CHD of all ages, especially pediatric age group **[9]**.

MDCT is increasingly used in patients with CHD when ECHO is not sufficient and MRI is contraindicated, unlikely to provide adequate image quality due to artifact or considered high risk due to scan time or anesthesia when needed **[3]**.

MDCT is an important diagnostic modality for selection of patients with CHD after intervention, from the neonate to the older pediatric patient. Evaluation of CHD is considered an appropriate indication on the most recent consensus document on the use of cardiovascular CT **[10]**.

MDCT has the characteristics of fast scanning speed, high resolution, powerful image post-processing and clear visualization of the anatomic structures of the cardiac chambers, coronary arteries and great vessels **[11]**.

Precise anatomical evaluation of RVOT and pulmonary arteries is substantial in imaging of certain types of cyanotic CHD as TOF, where ECHO is often inappropriate for evaluation of distal segments of the pulmonary arteries **[12]**. Moreover, MDCT is advantageous in estimating pulmonary artery size prior to dilatation or stenting procedures allowing precise devices sizing and obviating necessity for selective invasive angiography, as well as monitoring growth of pulmonary artery after successive palliative interventions in children **[13]**.

MDCT is the preferred technique for morphological preoperative evaluation of the Aorta, like Aortic arch anomalies, Aorticcoarctation and pseudocoarctation. It accurately identifies the Aorticcoarctation site, determines the degree of narrowing adding to definition of extent of hypoplasia of the Aortic arch aiding in choice of surgical technique performed **[13]**.

MDCT is increasingly used in assessing complex congenital venous anomalies. Precise delineation of the anomalous systemic venous return is often important in determining the proper approach for cardiac catheterization **[14]**.

The use of MSCT has allowed for a successful evaluation of a variety of coronary artery anomalies in pediatric age group. On the other hand, there is a great difficulty to assess congenital coronary artery anomalies by ECHO, which have been traditionally reserved for catheter angiography **[15]**.

Structured reporting for CHD should follow a sequential segmental analytic approach with a systematic description and included detailed description of lung parenchyma, airways, chest wall and vertebral anomalies given as common associations with other congenital abnormalities **[16]**.

In this study, we examined 50 childrenevaluatedby both ECHO and MDCT. Compared with the criterion standard, we found that the diagnostic sensitivity of ECHO and MDCT was generally high of 97.93% and 96.7%, respectively with equal specificity of about 83.3% for both. Each had its own advantages and disadvantages, but there was a high consistency between ECHO and MDCT diagnoses throughout this study. These results were relatively concordant with those of **[17]**, who found that the diagnostic sensitivity of ECHO and MDCT was 93.70% and 94.10%, respectively, yet with much higher specificity, in the fore mentioned study than ours, for both ECHO and MDCT of 99.50% and 98.50%, respectively.

Regarding the diagnostic accuracy of both ECHO and MDCT in the evaluation of CHD, there was no statistically significant difference between MDCT and ECHO with KAPPA = 0.762 and P-value = 0.3 in this study. Unlike Ahmed et al., and Sigal-Cinqualbre et al., **[15,18]** who found that there was an increase of diagnostic accuracy of MDCT overthat of ECHO, and also unlike Aiyin et al., **[17]**, who found ECHO was more accurate than MDCT in the diagnosis of CHD evidenced with a statistically significant difference with p-value <0.05 in these studies.

In diagnosing the cardiac structures malformations, our results showed that the diagnostic sensitivity of ECHO and MDCT was 100% and 92.9%, respectively. With a statistically significant difference between ECHO and MDCT in the diagnosis of PFO with p-value = 0.02. ECHO is more accurate than MDCT in PFO detection as MDCT had missed 6 cases with PFO in the study, which were all discovered by ECHO. However, there was no statistically significant difference between ECHO and MDCT in the diagnosis of other cardiac structures malformations with KAPPA = 0.627 and p-value >0.05 in these parts, indicating that both ECHO and MDCT can detect anomalies in these parts in the same accuracy.

These results were concordant with Aiyin, et al., **[17]**, who found that the diagnostic sensitivity of ECHO and MDCT in cardiac structures malformations was 99.50% and 94.80%, respectively with a statistically significant difference between ECHO and MDCT in the diagnosis of atrial septal defects with p-value = 0.034. This was also concordant with Harvey et al., **[19]**, who found that MDCT could not clearly distinguish small atrial septal defects less than 5mm in width.

Regarding atrio-ventricular valves assessment in this study, 2 cases with Ebstein's anomalies were included in this study were diagnosed by ECHO and not precisely diagnosed by MDCT, as well as

2 cases with prolapsing TV. This is due to inadequate valvular functional and motility assessment by MDCT, but MDCT well diagnosed the 2 cases with TV atresia. All of the 6 anomalies belonging to MV malformations encountered in this study were well diagnosed by ECHO, while MDCT discovered only 3 of them, which were MV atresia as a part of single ventricle and HLHS anomalies. This was also concordant with Harvey et al., [19], who was convinced of that the static images displayed by MDCT make it difficult to evaluate cardiac valves function and/or their dynamic changes.

There was no statistically significant difference between ECHO and MDCT in the diagnosis of heart-vascular connection malformations, including: 8 cases with DORV, 32 cases with PV stenosis, 2 cases with PV atresia, 7 cases with TGA, 2 cases with bicuspid Aortic valve, 1 case with Aortic subvalvular stenosis contributing to HOCM and last case with dilated Aortic root with p-value >0.05 for all these anomalies, which meansthat both modalities could diagnose these malformations accurately. This was concordant with Aiyin et al., [17]. On the other hand, some researchers deemed that MDCT cannot clearly exhibit abnormalities in the heart-vascular connections and it becomes more complicated with artifacts [20].

There was no statistically significant difference in the diagnostic accuracy between ECHO and MDCT in vascular malformations with KAPPA= 0.545 vs. 1, respectively, yet KAPPA was much higher for MDCT in this study. That was concordant with Aiyin et al., [17] diagnosing the vascular abnormalities, while these parts were detected by MDCT as explained below.

In this study, MDCT precisely diagnosed 3 cases with Aortic pseudo-coarctation and 7 of the 8 cases with Aortic coarctation, while few errors occurred by ECHO in the diagnosis of the site, length of stenotic segments and severity of the stenosis. Also, MDCT confirmed the presence of peripheral pulmonary stenosis in 20 cases and the presence of MAPCAs in 14 cases which were suspected by ECHO. Also, 10 cases had abnormal systemic venous drainage were discovered by MDCT, including: 6 cases with PLSVC, 1 case with interrupted IVC, 1 case with double IVC and 2 cases with retro-Aortic innominate vein, all were missed by ECHO. Throughout this study, we discovered by MDCT a case with LAD-right ventricular apex fistulous communication which was missed by ECHO and then confirmed by cardiac catheterization. Also, 3 cases with abnormal coronary arteries origin were discovered by MDCT and missed by ECHO. So, we found that MDCT may be a better choice than ECHO when diagnosing lesions in these vascular parts.

The same as Adaletli et al., [21], we found that there was a statistically significant difference between ECHO and MDCT in the evaluation of Aortic arch anomalies with p-value <0.05, as-MDCT was much better than ECHO in the diagnosis of Aortic arch anomalies encountered in the study. We discovered a case with double Aortic arch forming vascular ring with stenosis at isthmus and descending Aorta which were missed by ECHO. 4 cases with right-sided Aortic arch, 2 cases with aberrant right subclavian artery, 1 case with abnormal vertebral artery origin from Aortic arch and 1 case with bovine anomaly were all discovered by MDCT, but missed by ECHO. On the other hand, both ECHO and MDCT well diagnosed the single case with hypoplastic Aortic arch.

Our results also were concordant with those of Ahmed et al., [15], El-Gaber et al., [22] and Sigal et al., [18], who found that there was a statistically significant difference between ECHO and MDCT in the diagnosis of peripheral pulmonary stenosis, abnormal systemic venous drainage, MAPCAs with p-value <0.05 in these parts. Indicating that, MDCT is better than ECHO in the diagnosis of these anomalies, which is important for pre-operative and/or catheterization planning.

There was a statistically significant difference between ECHO and MDCT in the diagnosis of coronary arteries anomalies with p-value <0.05. So, MDCT that allowed for a successful evaluation of a variety of coronary artery anomalies in this study, as also was proved by Puranik et al., [23], who suggested that MDCT could be a non-invasive alternative imaging technique to conventional coronary angiography for screening the anomalous vessels of coronary arteries, because of its excellent spatial resolution and valuable 3D images.

Finally, there was no statistically significant difference between MDCT and ECHO in thediagnosis of anomalous pulmonary venous drainage with p-value >0.05, but MDCT was better than ECHO in the diagnosis of the 2 cases with supra and cardiac types of TAPVC, as well as the 3 cases with PAPVC, where few errors occurred by ECHO during their evaluation. Also, there was another merit of MDCT in the assessment of the surrounding lungs, e.g., congenital pulmonary hypoplasia, pulmonary sequestration or even lung consolidation, commonly associated with anomalous pulmonary venous drainage, which cannot be visualized

by ECHO, so that, MDCT has allowed good evaluation of abnormal venous connections, as also proven by Ahmed et al., **[15]**.

ECHO displays a 2D image, which relies on the experience of the technicians. Due to the limited acoustical window, it becomes more complex for the technicians to diagnose the abnormality in the macrovascular part by ECHO **[24]**.

Generally, MDCT helps in providing objective and precise morphologic information and is advantageous for depicting extra-cardiac anomalies thus helping in preoperative planning assessment of CHD patients. MDCT decreases potential diagnostic errors and increasing diagnostic confidence when the results of other cardiac imaging methods are equivocal or non-diagnostic **[25]**.

- The major limitation in this study and also in the compared studies was the relatively small sample size. As more patients populations would make the accuracy and specificity of MDCT in diagnosing CHD more reliable.
- Another limitation was that not all patients included in this study were subjected to diagnostic cardiac catheterization to allow confirmation of all data gained by ECHO and MDCT.
- It was not feasible to us to include whole types of CHD in the study. This was limited by special needs of referral from ECHO to MDCT.

Conclusions:

Several studies have compared the performance of ECHO and MDCT in coronary artery disease (CAD) patients. However, few studies have meticulously compared MDCT and ECHO in terms of cardiac structures malformations, malformations in the connecting area between heart and large vascular structures and vascular malformations **[17]**. This study evaluated the role of MDCT in CHD diagnosis and found that both MDCT and ECHO have a synergetic effect. Although, each has its own advantages and disadvantages, but, in conclusion, few errors and mis-diagnoses occurred when diagnosing the lesions in CHD whether with ECHO or MDCT.

Overall, ECHO is better than MDCT in the diagnosis of the cardiac structures malformations. Both modalities areaccurate in the diagnosis of heart-vascular malformations. The diagnostic sensitivity is higher for MDCT than ECHO in vascular structures evaluation. Thus, we recommend ECHO in the diagnosis of cardiac structures malformations, whereas MDCT is better forvascular malformations, while both can serve as good diagnostic modalities in heart-vascular connections malformations.

ECHO has no radiation risk, which makes it a better choice for children. Taking the diagnostic accuracy and application into consideration, we recommend ECHO in primary diagnosis establishing, rechecking and following-up the lesion, especially for of the cardiac structures and the heart-vascular malformations.

On the other hand, MDCT provides anatomic structural details and valuable images by the aid of high quality 3D images. So, we recommend MDCT in the diagnosis of macro-vascular malformations, tracing of MAPCAs and performing high quality coronary angiography. This study could serve as a theoretical basis for making a better choice in use of imaging methods when diagnosing CHD during preoperative planning.

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List of Abbreviations:

AAo : Ascending Aorta.
AHA : The American Heart Association.
AM : Acute marginal branch.
Ao : Aorta.
APCs : Aortopulmonary collaterals.
Ar : Aortic arch.
AS : Aortic stenosis.
ASA : Atrial sepal aneurysm.
ASD : Atrial septal defects.
AV : Atrioventricular.
AV : Aortic valve.
AVSD : Atrioventricularseptal defects.
BB : Beta blockers.
BT : Blalock-Taussig.
CAA : Cervical Aortic arch.
CAD : Coronary artery disease.
CAs : Coronary arteries.
CCTA : Cardiovascular computed tomography angiography.
CCTGA : Congenitally corrected transposition of the great arteries.
CHD : Congenital heart disease.
CM : Contrast media.
CMR : Cardiovascular magnetic resonance.
CPR : Curved planar reformation.
CRT : Cardiac resynchronization therapy.
CS : Coronary sinus.
CT : Computed tomography.
CTA : Computed tomography angiography.
Ds : Diagonal branches.
D : Dimension.
D- : Dextra.
dA : Descending Aorta.
DILV : Double inlet left ventricle.
DLE : Dose length product.
DOLV : Double outlet left ventricle.
DORV : Double outlet right ventricle.
ECG : Electrocardiogram.
ECHO : Echocardiography.
FO : Fossa ovalis.
FOV : Field of view.
GCV : Great cardiac vein.
Gy : Grays.
HLA : Horizontal long-axis.
HLHS : Hypoplastic left heart syndrome.
HU : Hounsfield unit.
IAA : Interrupted Aortic arch.
Is : Aortic isthmus.
IV : Intra-venous access.
IVC : Inferior vena cava.
Kvp : Kilovoltage peak.
L- : Levo.
LA : Left atrium.
LAA : Left atrial appendage.
LAD : Left anterior descending.
LCA : Left coronary artery.
LCCA : Left common carotid artery.
LCx : Left circumflex coronary artery.
LM : Left main coronary artery.
LPA : Left pulmonary artery.
LSCA : Left subclavian artery.
LV : Left ventricle.
LVATP : Left ventricular apical thin point.
LVOT : Left ventricular outflow tract.
mA : Milli-Ampere.
MAPCAs : Major Aorta pulmonary collateral arteries.
MCV : Middle cardiac vein.
MDCT : Multi-detector computed tomography.
minIP : Minimum-intensity projection.
MIP : Maximum-intensity projection.
MPA : Main pulmonary artery.
MPR : Multi-planner reformation.
MRA : Magnetic resonance angiography.
MRI : Magnetic resonance imaging.
MSCT : Multi-slice computed tomography.
MV : Mitral valve.
OM : Obtuse marginal branch.
PAH : Pulmonary arterial hypertension.
PAPVC : Partial anomalous pulmonary venous connection.
PDA : Posterior descending artery.
PDA : Patent ductusarteriosus.
PFO : Patent foramen ovale.
PLB : Postero-lateral branch.
PLSVC : Persistent left superior vena cava.
PS : Pulmonary stenosis.
PV : Pulmonary valve.
PVs : Pulmonary veins.
RA : Right atrium.
RAA : Right atrial appendage.
RI : Ramus intermedius.
ROC : Receiver operating characteristic curve.
ROI : Region of interest.
RPA : Right pulmonary artery.
RSVC : Right superior vena cava.
RV : Right ventricle.
RVOT : Right ventricular outflow tract.
RVOTO : Right ventricular out flow track obstruction.
SA : Sinoatrial.
SAN : Sinoatrial node.
SAX : Short-axis.
SD : Standard deviations.
SPSS : Statistical Package of Social Science.
Sv : Seivers.
SVC : Superior vena cava.
TAPVC : Total anomalous pulmonary venous connection.
TEE : Trans-esophageal echocardiography.
TGA : Transposition of the great arteries.
TOF : Tetralogy of Fallot.
TV : Tricuspid valve.
VLA : Vertical long-axis.
VRT : Volume rendering technique.
VSD : Ventricular septal defects.

دور التصوير المقطعى المحوسب للقلب فى تقييم أمراض القلب الوعائية مقابل أمراض القلب الخلقية عند الأطفال

أمراض الشرايين التاجية هى الأكثر شيوعاً فى جميع أنحاء العالم ولها معدل انتشار متزايد ملحوظ. وكان الهدف من هذه الدراسة هو تقييم دور الأشعة المقطعية فى تقييم الأوعية الدموية للقلب والشرايين التاجية فى طب الأطفال كأسلوب تخطيط غير جراحى قبل الجراحة ومقارنة نتائجها مع نتائج الموجات الصوتية على القلب.

\النتائج: شملت هذه الدراسة ٥٠ طفلاً، من المعروف أن لديهم أمراض الشرايين التاجية بواسطة الموجات الصوتية وتم إحالتهم لإجراء فحص الأشعة المقطعية لمزيد من التقييم قبل الجراحة. من بين ٥٠ طفلاً فى الدراسة، واجهنا ٢٧٣ حالة شاذة فى المجموع، والتى تم تحديدها فى ٢٣ نوعاً مختلفاً من أمراض الشرايين التاجية. تم إجراء الحساسية التشخيصية والنوعية وقيم KAPPA و P لكل من ECHO و MDCT و ROC وفقاً لقيم AUC لطريقتين.

فى تشخيص التشوهات القلبية الوعائية الخلقية MDCT و ECHO قمنا بمقارنة الحساسية والنوعية لـ فى إكتشاف تشوهات بنية القلب وتشوهات ECHO المختلفة بحساسية أعلى تبلغ حوالى ١٠٠٪ لـ تبلغ حوالى ١٠٠٪ للكشف. من MDCT اتصال القلب والأوعية الدموية، ولكن حساسية أعلى لـ اختبارات MDCT و ECHO تشوهات الأوعية الدموية. بالنسبة لتشوه الهياكل القلبية، يعتبر كل من إيجابية جيدة، ولكنها سلبية سيئة مع حساسية أكثر من ٩٢٪، ولكن النوعية فقط ٥٠٪. كانت قيمة لتشوهات الهياكل القلبية (٧٥٪ مقابل ٧١.٤٪) MDCT أكبر قليلاً من قيمة ECHO لـ ECHO AUC وتشوه اتصال القلب والأوعية الدموية (١٠٠٪ مقابل ٩٨.٦٪)، ولكنه أصغر قليلاً بالنسبة لـ أيضاً ECHO لـ KAPPA للتشوهات الوعائية (٩٦.٦٪ مقابل ١٠٠٪). كانت قيمة MDCT من لتشوهات الهياكل القلبية (٠.٦٢٧ مقابل ٠.٤٥) ولتشوه اتصال القلب MDCT أكبر قليلاً من لتشوهات الأوعية الدموية MDCT والأوعية الدموية و (١ مقابل ٠.٩٥١)، ولكنها أصغر بكثير من (٠.٥٤٥ مقابل١). لأمراض الشرايين التاجية عالية ECHO وMDCT.

\الاستنتاجات: الحساسية التشخيصية لكل من بشكل عام أفضل ECHO. لكل منها مزاياه وعيوبه. يعد ECHO بشكل عام له حساسية أعلى قليلاً فى تشخيص تشوهات الهياكل القلبية، خاصة بالنسبة لتشوهات الحاجز الأذينى مثل MDCT وكلاهما دقيق فى تشخيص تشوهات القلب والأوعية الدموية، بما فى ذلك: ASA و ASD و MDCT PFO ذو حساسية أعلى فى التفاصيل الهيكلية التشريحية. من ناحية أخرى، يوفر TGA و DORV للتشوهات الوعائية، والتضيق الزائف للشريان الأبهر، والتشوهات الشاذة فى قوس الأبهر، والتضيق. وبالتالى، فإننا MAPCAs الرئوى المحيطى، والتصريف الوريدى الجهازى غير الطبيعى، بينما MDCT أفضل فى تشخيص تشوهات الهياكل القلبية، فى حين أننا نوصى باستخدام ECHO لتشوهات الأوعية الدموية.