

Role of Electrocardiogram-Gated Multidetector Computed Tomography in Diagnosis of Congenital Heart Disease

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ABSTRACT

Aim of the work: this study aimed to assess the role of ECG gated multidetector computed tomography in detection and characterization of congenital heart diseases. **Patients and method:** this study was carried out in the Radiology Department of Ain Shams University Hospitals. A total of 30 patients presented with clinically/echocardiographically known to have congenital heart disease. They were 17(56.7%) females and 13 (43.3%) males. Their age was ranged from 3 days -18 year old. **Results:** Regarding the cardiac abnormalities, we found good agreement between Echo and ECG gated MDCT as regard cardiac abnormalities with kappa value measuring 0.771. Regarding great vessels anomalies, we found overall good agreement between Echo and MDCT where k measuring 0.790. As regard extracardiac findings, lung changes that were seen in MDCT only in form of lung consolidation in three cases (10%) and one case of unilateral lung hypoplasia (3.3 %). **Conclusion:** ECG gated MDCT is considered as an essential non-invasive diagnostic tool for the evaluation of congenital cardiac and extra cardiac great vessels. MDCT is complementary to the cardiac echocardiography especially in complex heart abnormalities.

Keywords: MDCT, ECG, congenital.

INTRODUCTION

Congenital heart disease (CHD) is one of the most commonly occurring congenital anomaly, affecting 4-10/1000 live births ⁽¹⁾. It is a major cause of serious morbidity and mortality. It is usually defined as clinically significant structural heart disease present at birth ⁽²⁾. The survival of CHD patients has also increased because of improvements in early diagnosis and treatment ⁽³⁾. Catheter angiography was used for many years as the investigation of choice for diagnosing CHD, the risk of complications associated with its invasive nature and use of contrast medium led to it being superseded by newer, non-invasive modalities. Echocardiography (ECHO), cardiac magnetic resonance (CMR), and cardiac computed tomography (CCT) are the primary modalities used for noninvasive cardiac imaging in patients with CHD ⁽¹⁾.

PATIENTS AND METHOD

This study was included 30 patients with suspicious or clinically/echocardiographically known to have congenital heart disease referred for MDCT examination.

Inclusion criteria

- Both sexes were included
- Pediatric patients (up to age 18 years old).

Exclusion criteria

- Patients are known to have absolute contraindication of contrast e.g. renal failure.

Procedure

Patients were subjected to:

- 1- Full history taking from the parents and elder children.
- 2- All patients underwent ECG gated cardiac CT examination of the heart and great vessels. The study was done in the CT unit at Ain shams university hospitals.

Patient preparation

- Explanation of the study to patients or his/ her care giver and obtaining consent. Measuring patient body weight for calculation of amount of contrast media and sedative material if indicated.
- Fasting for 3 hours and checking serum creatinine before contrast administration.
- Placement of Peripheral venous line in a right upper limb vein
- Children who were below 5 years old and uncooperative were orally administered 10% chloral hydrate, at a dose of 50 mg/kg, 30 min before MDCT scanning.
- Children aged 5 years or older underwent the study without sedation and were trained on breathing exercise if cooperative.
- The patient will be supine and middle in CT gantry. ECG leads will be put on the chest of patient.

Procedure duration: 10 -15 minutes.

Method:

- Patients were scanned with MDCT machines (80 and 128 -slice spiral CT). The radiation dose was kept to minimum by reducing the kilo voltage and the recent machines adjust tube current according to the patient's weight. ECG leads were put on the patient's chest.
 - A preliminary scout was taken.
 - Dual injector was used: syringe A: non-ionic contrast (1-2 ml /kg) and Syringe B: 20 ml saline. Nonionic contrast agent was injected through a peripheral venous line by using a power injection followed by 20 ml saline. The total contrast volume used for pediatric CT is

typically 1-2 ml/kg until standard adult contrast volumes are achieved.

- 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 region of interest on a monitoring sequence.
- Examination of the heart was then performed. Sequential series of images in arterial and subsequent phase of enhancement are to be taken to ensure opacification of both sides of the heart and all extra-cardiac vessels.
- All reconstructed images will be transferred to a dedicated workstation. Multiplanar reformation (MPR), maximum intensity projection (MIP) and volume rendering technique (VRT) will be used.

The study was done after an informed written consent was taken from each participant in the study.

RESULTS

A total of 30 patients were presented with clinically/echocardiographically known to have congenital heart disease. They were 17(56.7%) females and 13 (43.3%) males. Their age ranged from 3 days -18 year old.

Age: Their age ranged from 3 days -18 year old. Those who below <1 year represented 50%. 1-10year represented 30% and 11-18 year represented 20%

Table 1: shows the agreement and 95% confidence interval between ECHO and ECG gated MDCT

abnormality	Kappa value	% Confidence interval	Strength of agreement
Aortic abnormality	0.727	0.488 to 0.967	good agreement
Pulmonary vein	0.526	0.078 to 0.974	Moderate agreement
VSD	0.800	0.590 to 1.000	Very good agreement
ASD	0.851	0.653 to 1.000	Very good agreement
Atria	1	1	Perfect agreement
Ventricles	0.862	0.678 to 1.000	Very good agreement
valves	0.333	0.082 to 0.585	Fair agreement
Pulmonary artery	0.769	0.523 to 1.000	good agreement
PDA	0.535	0.159 to 0.911	Moderate agreement
SVC	0.474	0.126 to 1.000	Moderate agreement
IVC	1	1	Perfect agreement
Coronary	0.034	0.013 to 0.082	poor agreement

CASES

Case 1: A 5 days old female patient presents with difficulty in breathing. Her Echo revealed PDA, anomaly in pulmonary veins, ASD, right atrial and ventricle enlargement. ECG gated multi-detector CT angiography revealed: Superior and inferior pulmonary veins are seen abnormally drained in vertical vein that ends in right atrium via dilated coronary sinus (cardiac type), Large ASD, No PDA and Dilated right atrium and ventricle.

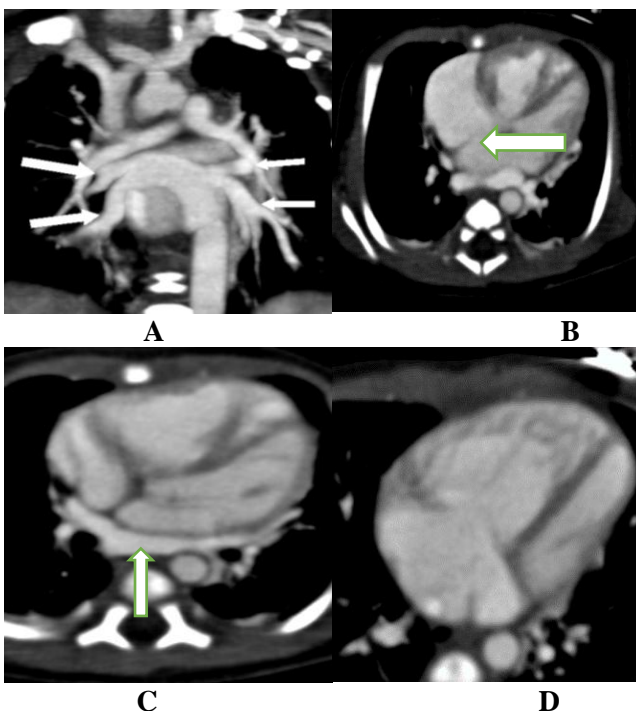


Fig. 1: ECG gated Cardiac CT a) coronal reformat shows abnormal drainage of all pulmonary veins (arrows) b) axial view shows ASD (arrow) and dilated right atrium and ventricle. c) Axial view shows all pulmonary veins drain in common channel(arrow) d) axial view shows that vertical vein drains in coronary sinus. Diagnosis: TAPVR (cardiac type) with large ASD

Case 2: A 2 months old female patient presents with difficulty in breathing and cyanosis. Echo revealed VSD, dilated right atrium and ventricle, hypoplastic arch, dilated main pulmonary artery and its branches and left ventricular hypertrophy. ECG gated multi-detector CT angiography revealed:

- Dilated main pulmonary artery that gives origin to normal caliber right and left pulmonary branches.
- Aortic coarctation is noted, narrowest segment measuring 3.7 mm, noted 5.9 mm distal to origin of left subclavian artery.
- Hypoplastic aortic arch.
- No PDA is noted.
- Multiple VSDs are noted with largest measuring 4.5 mm.
- Right ventricle hypertrophy.
- Left ventricle shows no CT abnormality.
- Bibasilar lung consolidation is noted.

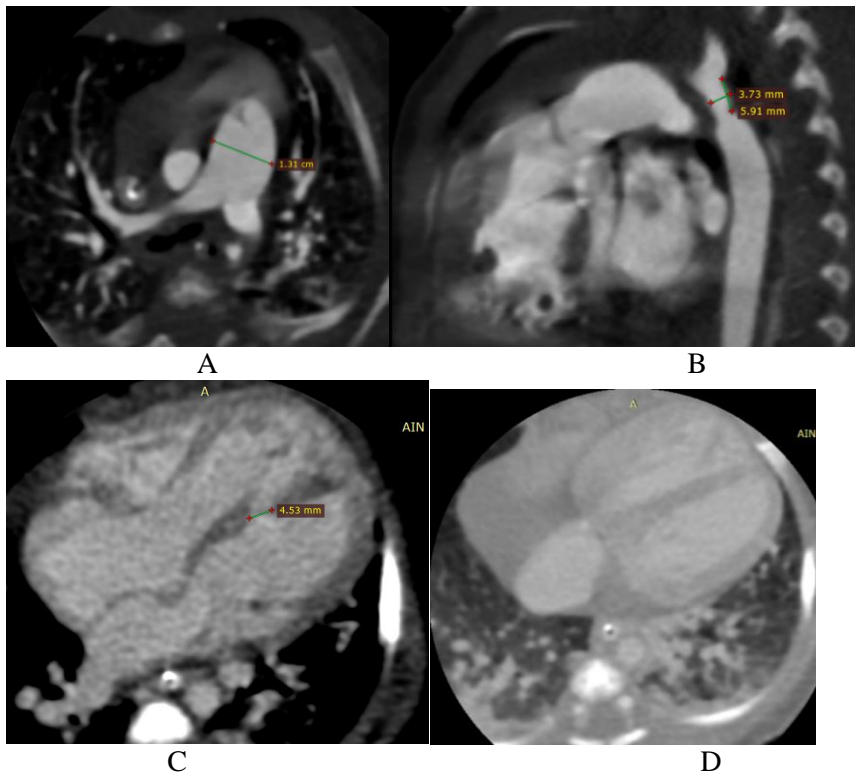


Fig 2: ECG gated Cardiac CT a) axial view shows dilated main pulmonary trunk b) sagittal reformat shows coarctation of aorta, it measures 3.7 mm and away from origin of the left subclavian by 5.9mm c) axial view shows one of VSDs and right atrium and ventricle dilatation. D) Axial view shows bibasilar lung consolidation **Diagnosis:** pulmonary hypertension, VSD, ASD, Aortic coarctation and pulmonary lung consolidation.

Case 3: A 17 year old male patient presents with easy fatigability. Echo revealed ASD, marked dilation of right atrium and ventricle, dilated pulmonary artery. ECG gated multi-detector CT angiography revealed:

- Normal caliber pulmonary trunk which gives origin to normal caliber of both right and left pulmonary arteries.
- Right superior pulmonary vein is seen draining into SVC and right accessory pulmonary vein is seen draining into right atrium.
- Left superior and inferior pulmonary veins drain normally into left atrium.
- Sinus venosus ASD measuring 16 mm.
- Aberrant right subclavian.
- Dilated right atrium and ventricle.

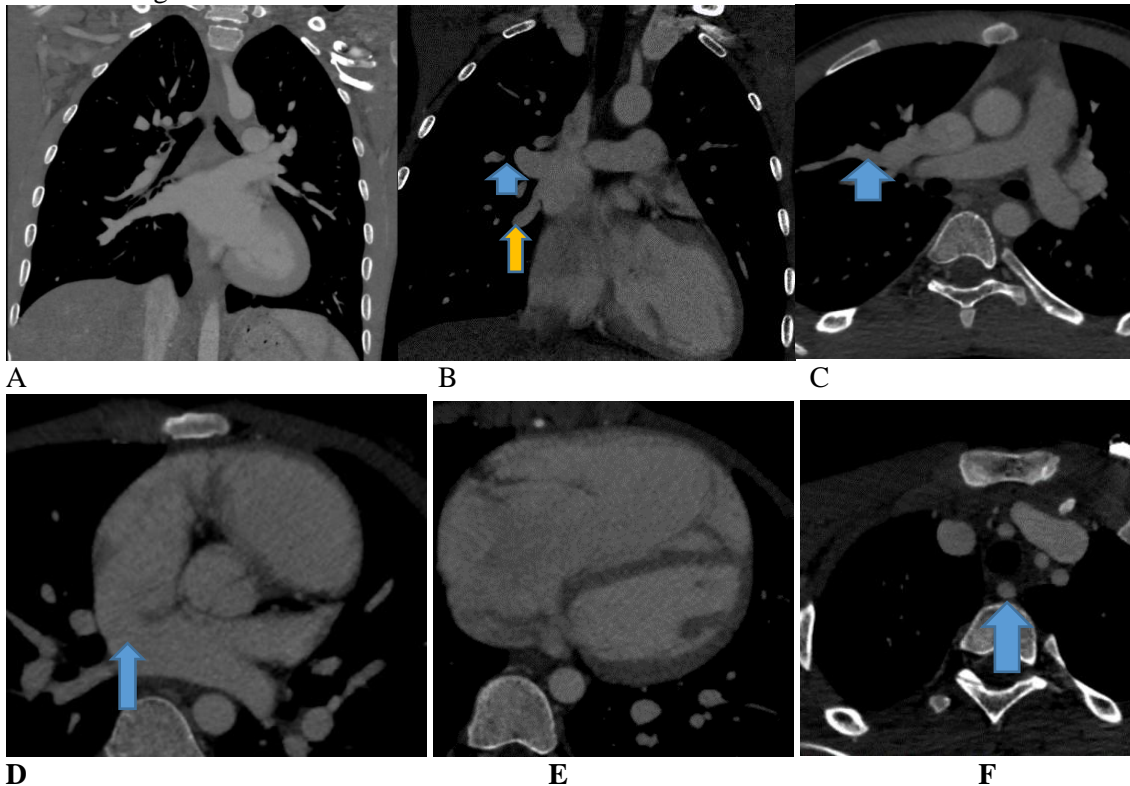


Fig 3: ECG gated Cardiac CT a) coronal reformat shows normally drainage of left superior, inferior and right inferior pulmonary veins into left atrium. b) Right superior pulmonary vein (arrow) is seen draining into SVC and right accessory pulmonary vein (orange arrow) is seen draining into right atrium. c) axial view show right superior pulmonary vein is seen draining into SVC d) Axial view shows ASD (arrow) e) axial view shows dilated right atrium and ventricle f) axial view shows aberrant right subclavian (arrow). Diagnosis: partial anomalous venous return and sinus venosus ASD with subsequent dilation of right atrium and ventricle. Aberrant right subclavian.

DISCUSSION

Thirty patients (inclusive of 13 male and 17 female) were enrolled for this study with an age ranging between (3 days –18 years). Patients were referred for cardiac MDCT after Echo was done and we assessed the agreement between Echo and MDCT. Regarding the cardiac abnormalities, we found good agreement between Echo and ECG gated MDCT as regard cardiac abnormalities with kappa value measuring 0.771. This is in agreement with **Zhang *et al*** who reported that the accuracy of MDCT in diagnosis of cardiac malformation ranging between 88.37%, and 97.69%⁽⁴⁾. Also in

agreement with **Bu *et al.*** who reported that the sensitivity of MDCT for the diagnosis of cardiac malformations was 98.2% (57/58), not significantly different from the value of 96.6% (56/58) for TTE⁽¹⁾.

As regard cardiac chambers abnormalities, we found perfect agreement between Echo and ECG gated MDCT as regard atrial changes which were in form of single atrium and atrial dilation. Atrial dilation was attributed to volume overload. A very good agreement was noted as regard ventricular abnormalities which were in form of single ventricle, right ventricular dilation or hypertrophy

and left ventricular dilation or hypertrophy. The discrepancy between Echo and MDCT was in two cases that ECG gated MDCT detected two cases of asymmetrical ventricles with VSD connecting them but Echo detected them as a single ventricle. In our study, MDCT detected VSD in 18 cases, yet Echo detected it in 15 cases. There were three cases that were missed by Echo containing more than one VSD. This may be attributed to their apical position. As regard the ASD, Echo detected 11 cases but MDCT detected only 9 cases of small ASD. In agreement with **Bu et al**⁽¹⁾ who reported that one case of small atrial septal defect was missed by MDCT. Unlike Echo, MDCT displays static images and is unable to display hemodynamic changes in small ASD, this may be an explanation for that.

As regard coronary vessels in our study, ECG gated MDCT had a rule in detection of coronary course in all cases. It detected one case (3.3%) with anomalous origin of RCA from left coronary cusp and its slit like origin (malignant course) and excluded calcification from another case reported to have it by Echo. This is in agreement with **Angelini et al** who reported that 5.6% of people has coronary arterial anomaly. MDCT was more sensitive in delineating the coronary arteries than TTE⁽⁵⁾.

Regarding great vessels anomalies, we found good agreement between Echo and MDCT where k measuring 0.790. This is in agreement with **Shehata et al** who reported that there is good agreement was obtained for complex vascular anomalies where k measuring 0.776⁽⁶⁾.

Regarding aortic abnormalities, MDCT was able to detect 14 cases of aortic abnormalities while Echo had seen them in 10 cases. These abnormalities were in form of aortic coarctation, arch hypoplasia, right sided aortic arch and overriding of the aorta. The four cases representing discrepancy between Echo and MDCT, two of them were aortic coarctation and the other two cases were right sided aortic arch. These four cases were detected by ECG gated MDCT. In agreement with **Kamal et al** who reported that the overall sensitivity of MDCT angiography for diagnosis of the coarctation of the aorta was (100%) which was higher than that of Doppler echocardiography (91%)⁽⁷⁾. Also in agreement with **Osama et al** who reported that MDCT detected three cases of right sided aortic arch and Echo detected two cases and it may return to technical limitation of echocardiography⁽⁸⁾.

Regarding the variant branching of vessels, there were two cases in our study of aberrant subclavian

artery that were reported by MDCT and not by Echo. As regard pulmonary artery, 5 cases of pulmonary dilation were detected in our study by both Echo and MDCT. MDCT detected 9 cases of pulmonary stenosis and Echo detected 7 cases. This is in agreement with **Liu et al** who reported that MDCT was slightly more accurate than catheterization (99.8% versus 95.9%) in overall pulmonary artery characterization. The results showed that TTE was the least accurate modality. The low accuracy of echocardiography (85.9%) is primarily attributable to a low sensitivity (72.9%)⁽⁹⁾. Regarding anomalous venous return can be categorized into TAPVR and PAPVR. In our study, TAPVR (total anomalous pulmonary venous anomalies) of cardiac type was detected in three cases, two of them were detected by ECG gated MDCT and Echo and one case was reported in Echo as PAPVR and MDCT reported it as TAPVR. Two cases of PAPVD (partial anomalous pulmonary venous return) cases weren't reported in echocardiography. One case is seen containing right superior pulmonary vein draining into SVC (supracardiac type) and accessory pulmonary vein draining into right atrium (cardiac type). The other case with right inferior pulmonary vein draining into IVC. In agreement with **Osama et al** who reported that MDCT correctly depicted the TAPVR (Total anomalous pulmonary venous return) and PAPVR (Partial anomalous pulmonary venous return) types of pulmonary venous anomalies with sensitivity 100%, and specificity 100%. The specificity of echocardiography was 50% for these findings⁽⁸⁾.

As regard systemic venous return in our study, MDCT reported three cases while Echo reported one case of SVC abnormality (left persistent SVC). IVC abnormality (interrupted IVC) was present in one case and detected by both Echo and MDCT. In agreement with **Li et al** who reported that Echo underdiagnosed one double superior vena cava and one anomalous inferior vena cava drainage. The diagnostic accuracy of Echo and MDCT were 96.30% and 98.30%, respectively⁽¹¹⁾. Also **Shehata et al** reported that MDCT was superior to echocardiography in the assessment of systemic with a sensitivity, specificity of TTE and MDCT for assessing the systemic venous anomalies were (83.3%, 100%) and (100%, 100%) respectively⁽⁶⁾.

As regard aortopulmonary connections in our study namely PDA the MDCT detected 7 cases with PDA and Echo couldn't give a clue about the presence of PDA in four cases. One case there is retroverted PDA, one is associated with right sided aortic arch and last two were tiny. This is in

agreement with **Seif El Dien *et al.*** who reported that four cases with PDAs were missed by Echo. They were associating with tetralogy of Fallot and were tiny⁽¹²⁾.

As regard MAPCAS (major aortopulmonary collaterals), in our study, there were 3 cases (10%) which detected only by ECG gated MDCT. MDCT detected well noted left sided MAPCAS in two cases and tiny left sided MAPCAS in the other case. This is in agreement with **Goitein *et al.*** who reported that MDCT yielded additional diagnostic information in case of MAPCAS by 92% since only one case was detectable by echocardiography out of 12 diagnosed by MDCT⁽¹³⁾. As regard extracardiac findings in our study, lung changes that were seen in MDCT in form of lung consolidation in three cases (10%) and one case of unilateral lung hypoplasia (3.3 %). This is in agreement with **Shehata *et al.*** who reported that MDCT is superior to echocardiography in diagnosis of associated pulmonary lesions like; atelectasis, pneumonia, pulmonary edema, pulmonary embolism and pneumothorax unsurprisingly, in our study airway abnormalities were only detected by MDCT⁽⁶⁾.

As regard situs abnormality in our study, there is one case with situs inversus detected by both Echo and MDCT. There were some limitations in this study, firstly not all patients included in this study were subjected to surgery or catheterization. Second the sample size of the present study is relatively small and future studies with greater populations should be considered.

For aforementioned data, we can say that Echo and ECG gated MDCT have a complementary role in diagnosing the congenital cardiac anomalies while ECG gated MDCT is more valuable and reliable method of diagnosing the Extra cardiac great vessels congenital anomalies. This is in agreement with **Bu *et al.***⁽¹⁾ and **Goo**⁽¹⁴⁾ who reported that echocardiography is considered the method of choice for diagnosing the vast majority of congenital cardiac defects, CT plays a complementary role by providing objective and precise morphologic and functional information and is advantageous for depicting extra-cardiac abnormalities thus helping in pre-operative planning assessment of CHD patients.

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