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Role of Spiral CT of Chest in Diagnosis of Intrathoracic Major Vascular Abnormalities

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ABSTRACT
Background: this study was assessed, it enrolled 30 patients (9 males and 21 females) It included isolated extra-cardiac vascular anomalies in 14 patients and congenital complex vascular anomalies in 16 patients.
Objective: To describe the role of Multi detector CT angiography (MDCT) in diagnosis and evaluation of intra thoracic major vascular abnormalities.
Results: In this study the role of Multi-slice CT angiography in the evaluation of conotruncal and pulmonary venous anomalies was assessed, it enrolled 30 patients (9 males and 21 females) with an age range between 30 days - 39 years (mean age 108 months: 9 years). It included 14 patients with isolated extra cardiac vascular anomalies and 16 patients with congenital complex vascular anomalies.
Conclusion: CTA provide the confident detection and exclusion of isolated extra- cardiac vascular anomalies and intra thoracic /complex intra thoracic vascular anomalies with superb anatomical description. In recent years, MSCT technology has advanced rapidly providing a major, additional, non-invasive diagnostic tool for the evaluation of congenital heart disease.
Keywords: Tetralogy of Fallot, ventricular septal defect

Manuscript

I. Background:

Congenital thoracic arterial anomalies can be incidentally detected in adults from imaging studies performed for other indications .Multi detector CT angiography (MDCT) plays a critical role in the non invasive assessment of these anomalies ,Like congenital arterial anomalies such as double aortic arch, right aortic arch, aortic coarctation, pseudocoarctation, interrupted aortic arch, interruption (absence) of the pulmonary artery, pulmonary artery sling, pulmonary artery stenosis, transposition of great vessels, truncus arteriosus, aortopulmonary window, and patent ductus arteriosus [(1)].

For example interrupted aortic arch is a rare congenital malformation of the aortic arch defined as a loss of luminal continuity between the ascending and descending portions of the aorta, Type A interrupted aorta usually associated with an aortopulmonary window, an atrial septal defect, a ventricular septal defect, and a patent ductus arteriosus on MDCT imaging [(2)].

Another example seen at Tetralogy of Fallot (TOF) which is classically characterised by the combination of ventricular septal defect (VSD), right ventricular outflow tract obstruction (RVOTO), overriding aorta, and a late right ventricular hypertrophy [(3)].

Common associations of Fallot's Tetralogy include pulmonary artery atresia that varies from mild hypoplasia to complete absence of the main pulmonary artery or the non-confluence of its branches. In severe cases, the pulmonary flow is maintained by a patent ductus arteriosus PDA, while the main pulmonary artery and its branches are intact by major aorto-pulmonary collateral arteries MAPCAs [(4)].

The MAPCAs are present from birth and are alternatives to the systemic pulmonary arterial supply. They usually arise from the descending thoracic aorta but may also take their origins from the subclavian or coronary arteries and the abdominal aorta [(5)].

Other abnormalities include coronary artery abnormalities; the most common is a right coronary artery arising from the left anterior descending (LAD) artery, right aortic arch usually in a mirror image, an atrial septal defect (ASD) and a left superior vena cava [(6)].

II.PATIENTS AND METHODS

This study was conducted from December 2015 to April 2019 at National Heart Institute on 30 patients were referred from clinicians. 9 males and 21 females suspected or diagnosed of having congenital cardiac or extra cardiac anomalies on examination and echocardiography. They ranged in age from 30 days to 39 years old. Two of them were post-operative cases.

CT angiography examination of the heart and thoracic vessels under the following inclusion and exclusion criteria

Inclusion criteria:

- Limited visualization of congenital heart anomalies.

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- Difficulty in demonstrating pulmonary arteries by echocardiography
- Confirm the presence and identify the number, size and extent of major aortopulmonary collateral arteries (MAPCAs).
- Identify normal and pathologic pulmonary venous anatomy.
- Follow up of postoperative cases to assess patency of connections.

Exclusion criteria: Clinically unfit patients eg. Severe asthma. Contrast hypersensitivity. (Creatinine > 2 mg/ dl).

Technique of Examination:

Data acquisition*:*

Scanner:. The patient lies on the CT table in supine position. A scanogram is obtained. Scan range: from the root of the neck including the proximal aspects of the common carotid and subclavian arteries down to the level of the portal vein inferiorly. This range is important to detect associated aortic arch branch anomalies, situs inversus, situs ambiguous, abdominal aorta coarctation and infia-diaphragmatie type of total anomalous pulmonary venous drainage. ECG gating: with low dose protocol was performed in all cases.

Contrast injection: Non- diluted. Non-ionic contrast material was used. (Omnipaque 300-350; Nycomed Amersham, Princeton, *NJ).*

Dose: 1.5 ml/kg.

Rate of injection: 1.5 ml/sec.

Empiric scan delay between 7 and 15s from the onset contrast administration to start of scan acquisition determined before start of the study,

Sterile syringe for manual injection was used in to volumes up to 20ml in about 45 patients,

Automatic power injector was used in higher volumes contrast.

Scan Parameters: kVp: low dose protocol 80-100 kVp. mAs: 100:120 mAs. Slice thickness: 2 mm. Pitch: 1.3. Reconstruction increment 1.5 mm. on- diluted, Non- ionic contrast material was used.

Multi-phase examination: of the heart is then performed. Sequential series of images in the mid venous and mid arterial and delayed phases of enhancement to ensure opacification of both sides of the heart and all extra-cardiac vessels. The first series is performed in the caudocranial direction to decrease contrast agent-related artifacts and to achieve homogeneous contrast enhancement while the second one is in the craniocaudal direction, The third one is performed in the caudocranial direction again.

Post Procedural Assessment:

Axial images are rapidly reconstructed at 1.0 mm slice thickness and increment of 0.8 mm and reviewed to ensure satisfactory quality of the images. 15-30 minutes after the procedure the patient is kept under observation till recovery of sedation. Nothing by mouth till complete recovery. The peripheral venous line is then removed.

Image reconstruction and post processing: All images were transferred to the Vitrea 5.2 workstation for post processing. An image containing only the bones is created by using the appropriate threshold level while trying to keep all the data from the vascular structures out of the image. Subtraction is then done by this image from the source images to get a set of images with no bones within. Some views were taken before bane subtraction and others were taken afterwards. Three dimensional ***maximum intensity projections (MIP), volume rendering (VR), multi planar (MPR) and curved planer reformations (CPR)*** were created at different angles of views.

Multi planar reformation (MPR): Reformation planes are defined by projecting a line cm one of the transverse sections so that the resultant MPR images will be perpendicular to the transverse plane and parallel to the projected line. MPR were applied to all patients. The variable imaging planes of MPR simultaneously display the pulmonary veins on the same imaging plane and identify the draining sites of the vertical vein to the systemic veins. Thin MPR images are used for precise measurements of vessels.

Curved planar Reformat (CPR): Curved planar images are used to visualize curved vascular structures. It was of great value in assessment of the caliber of the thoracic aorta and main pulmonary arteries.

Volume rendering (VR): VR obtained after editing of axial images to remove bone structures and other soft tissues. The volume-rendering technique was particularly useful for displaying structures that course parallel or oblique to the transverse plane. It was helpful in the demonstration of the spatial relationship of the extra-cardiac vessels as well as visualization of the pulmonary and systemic venous drainage.

Maximum intensity projection (MIP): Peripheral vessels and airways are often better seen as a«P assimilation of sections in a volume slab. With this technique, CT images are acquired at their routine section thickness and then combined in multiples, or "slabs* to create a thicker image. This technique was best used in assessment of relation of the great vessels of the heart and pulmonary vein drainage. No complications what so ever occurred during the multi-slice *CT* angiography examination including contrast extravasation or reaction.

III. RESULTS

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This study enrolled 30 patients (9 males &21 females) with an age range of 30 days - 39 years (mean age 108 months (9 years)).

A total of 30 intra thoracic vascular anomalies were confirmed by MDCT in 30 patients that were grouped into 1. isolated extra-cardiac vascular anomalies in 14 (46.6 %) patients and 2.congenital complex vascular anomalies in 16 (53.3%) patients.

The most common anomaly detected in this study was pulmonary venous drainage (8 cases TAPVD and (4 cases PAPVD) for approximately 40% of all cases while the least common were TOF accounting for 10 % of all cases.

The prevalence type of pulmonary venous anomaly encountered in this study was total anomalous pulmonary venous return (TAPVR) 66 % of cases.

In order to simplify and analyze the extra cardiac abnormalities depicted in the patients the abnormalities are classified as follows: Aortic abnormalities. Pulmonary artery abnormalities(in our study, it is a part of TOF anomaly). Aorto-pulmonary abnormalities. Pulmonary venous abnormalities.

1.Aortic abnormalities

The major aortic abnormalities in this study included interrupted aortic arch, coarctation of the aorta, Right aortic arch, supra valvular aortic stenosis, bicuspid aortic valve and subaortic membrane.

2.Aorto-pulmonary connections

The cases examined for aorto-pulmonary connections in our study is only Truncus arterous type I with dilated truncal root and ascending aorta

3.Pulmonary venous abnormalities

Pulmonary venous abnormalities were classified into partial (PAPVR) and total (TAPVR) pulmonary venous anomalies with its three subtypes (supracardiac, cardiac and infracardiac).

- **Systemic venous abnormalities (in both isolated extra cardiac and intra thoracic /complex intra thoracic vascular anomalies**

  Systemic venous abnormalities detected in the study were classified into persistent left SVC and interrupted IVC.

- **Post-operative cases(intrathoracic /complex intrathoracic vascular anomalies).**

  CT proved to be a reliable technique in follow up of post operative patients with congenital heart anomalies.

Table (1): Sex distribution of the patient population.

Male	**Female**
9(30%)	21(70%)

Table (2): Number of patient according to clinical complaint

Feeding problems	5(16.6%)
failure of growth	3(10%)
Post operative follow up	2 (6.6%)
Cyanosis	13(43%)
Chest infection	7(23%)

Table (3): Number of patients according to type of conotruncal anomaly.

TOF	3 (10%)
Truncus arteriosus	1 (3.3%)
TGA	2 (6.6%)
DORV	4 (13.3%)
TAPVD	6 (20%)
PAPVD	4 (13.3%)
Aortic abnormalities	7 (23%)

Table (4): Number of patients according to type of pulmonary venous anomaly

PAPVR	4 (13.3%)
TAPVR supracardiac	1 (3.3%)
TAPVR cardiac	2(6.6%)
TAPVD infracardiac	3(10%)
TAPVD mixed (supra and infra cardiac)	1 (3.3%)

Table (5): Number of patients according to type of aortic abnormality.

Abnormality	**CT**
Right AA	1(3.3%)
Interrupted AA	2 (6.6%)
Supra valvular stenosis	1(3.3%)

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Coarctation	3(10%)
Subaortic membrane	1 (3.3%)

Table (6): Number of cases of aorto-pulmonary connection detected.

Aorto-pulmonary connection	**CT**
Truncus arterous type I	1 (3.3%)

Table (7): Number of cases pulmonary venous abnormalities detected by CT

Abnormality	**CT**
PAPVR	4(13.3%)
TAPVR	8(26.6%)

Table (8): Number of cases systemic venous abnormalities by echocardiography and CT.

Abnormality	**CT**
Persistent left SVC	5 (16.6%)
Interrupted IVC	1 (3.3%)

Table (9): CT findings in postoperative cases.

Case	**Number of cases**	**CT findings**
Post VSD closure	1 (3.3%)	Status post VSD closure with tiny residual outlet VSD tight RVOT stenosis with poststenotic sacuular ROVT anuyrusm.
Congenitally corrected TGA	1 (3.3%)	• Situs inversus • Congenitally corrected TGA with large outlet VSD. • Dilated pulmonary arteries

IV. DISCUSSION

The clinical care of adult and paediatric patients with complicated congenital heart disease requires a precise 3D examination of the cardiac and associated vascular anatomy.

3D imaging must be able to show the morphologies of the major arteries, proximal branch pulmonary arteries, and anomalous pulmonary venous or systemic connections, as well as their spatial relationships , 3D information of extra cardiac morphological characteristics may determine subsequent surgical intervention, follow up the residuals of interventions, and assist with estimation of prognosis [(7)].

Goo et al. [(8)] reported that by applying the ALARA (as low as reasonably achievable) principle as far as possible in neonates and babies with CHD, can be performed by avoiding a preview scan, using 70-kV settings, adaptation of the mAs to child's weight as well as systematic protection of non-scanned organs.

Bayraktutan et al. [(9)] reported that sedation was necessary to avoid motion artifact. He used either 50–100 mg/kg of oral chloral hydrate or 2–6 mg/kg of intravenous , ***In this study*** 17 sedated in a similar fashion by oral and minor IV anesthesia using a weight related protocol under direct supervision of a specialized anesthesiologist, The 13 patients not sedated Only reassurance was adequate to carry on technique. No sedation related complications were encountered in the study.

In this study the cardiac CT dose was 1.12 msv to 4.47 msv which agreed with ***Bayraktutan et al.*** [(9)] regarding contrast administration, ***Ji et al.*** [(10)] stated that Iodinated contrast medium (Schering Ultravist, Iopromide, 350 mg I/ml, Berlin, Germany) was injected via unilateral peripheral veins in the elbow or back of the hand at a volume of 2.0 ml/kg body weight with a saline chaser of 1.0 ml/kg body weight. The delay between the start of injection and the start of data acquisition was set at 40 seconds. Injection rate was calculated at total injected volume divided by 30. For example, a 15 kg child with peripheral access would be injected with 30 ml of contrast medium and 15 ml saline at 1.5 ml/s.

In this study we injected contrast at a rate of 1.5 ml/sec utilizing an empiric scan delay technique between 7 and 15 s from the onset of contrast administration to start of scan acquisition determined according to the weight of the patient and congenital anomaly under question. We did not perform automatic bolus tracking as in many cases there was left to right shunts e.g. ASD, VSD and PDA making the process difficult and time consuming.

The scan parameters used in our study was similar to that used by ***Bayraktutan et al.*** [(9)] who used slice thickness of 2 mm.

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Image reconstruction, post processing and interpretation of the images in our study were performed using a dedicated workstation. First, thorough review of the thin slice multi planar (MPR) and curved planar (CPR) images are performed using a system of assessment based on the anatomical and segmental/ sequential approach.

Then three dimensional maximum intensity projections (MIP), volume rendering (VR), images are obtained. The VRT images were an essential tool to define the precise spatial relations of the complex anatomical structures especially in patients with conotruncal and pulmonary venous anomalies. MIP and 2D reformation were beneficial in tracing the curved structures and tortuous vessels such as pulmonary arterial tree and MAPCAS.

In this study confident detection and exclusion of extra- cardiac vascular abnormalities was possible and when the abnormality was present high level of accuracy of its anatomic description was achieved.

In this study conotruncal anomalies represented 46% of the cases while pulmonary venous anomalies represented 40 %. The commonest conotruncal anomaly was DORV followed by TOF. The commonest pulmonary venous anomaly was TAPVR accounting for 66% of the cases.

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% [(11)].

Recognition of systemic venous anomalies especially left SVC is of importance ,it is considered in patients undergoing Pacemaker or defibrillator placement, and in the use of retrograde cardioplegia for surgical procedures requiring cardiopulmonary bypass [(12)].

CT angiography plays a significant role in the pre and post-operative evaluation and follow up of interventional procedures. The commonest operations performed in conotruncal and pulmonary venous anomalies include; Blalock Taussing shunt, Glenn's operation, Fontan operation and unifocalization of the MAPCAS [(12)].

We agree with ***Goo et al.*** [(13)] that, the primary function of MDCT in CHD patients is structural evaluation of extra-cardiac vascular anatomy comprising thorax and upper abdomen. It grants Congenital Extra-Cardiac Vascular Anomalies.

Also wee agree with **Zhang *et al.*** [(14)] concluded that Cardiac MDCT plays a major role in the diagnosis and follow-up of congenital heart defects,). Detailed morphological information can be obtained by MDCT even in complex intracardiac defects with an accuracy of 88.37%.

In our study we reported that isolated extra-cardiac vascular anomalies in 14 (46.6 %) patients and congenital complex vascular anomalies in 16 (53.3%) patients so , We disagree with Mataciunas et al , who reported that (50.7%) of patients had extra cardiac vascular pathology only, (5.6%) had extra cardiac non-vascular pathology only and (40.9%) had both extra cardiac vascular and nonvascular pathology.

In our study The most common anomaly detected in this study was pulmonary venous drainage (8 cases TAPVD and (4 cases PAPVD) for approximately 40% of all cases and the least common were TOF accounting for 10 % of all cases we disagree with Nie et al. [2] that reported that most common extra cardiac vascular anomaly is PDA was detected in (29.3%) and aortic CoA in (30.7%) while, ***Mataciunas et al.*** [(15)] reported that the highest incidence (70%) was with PDA then aortic CoA (28%).

Also we disagreed with ***Long et al.*** [(16)] who found that pulmonary artery atresia or sever pulmonary artery stenosis and Fallot tetrollogy are the most common also Nakhla [4] studied the role of MSCTA in evaluation of conotruncal anomalies and found that the most common conotruncal anomaly was pulmonary atresia with VSD accounting for approximately 33% .

However CT is performed with ionizing radiation , a variety of imaging parameters can be used to minimize ionizing exposure ofv children and maintain image quality.

V. CONCLUSION

CTA provide the confident detection of isolated extra- cardiac vascular anomalies and intra thoracic /complex intra thoracic vascular anomalies. it is non-invasive and precise diagnostic tool for the evaluation of congenital heart disease.

List Of Abbreviations

ASD	Atrial septal defect
CT	Computed tomography
CTA	CT angiography
CHD	Congenital heart disease
MDCTA	Multi-detector CT angiography
LV	Left ventricle
MAPCAs	Major aorto-pulmonary collateral arteries
MIP	Maximum intensity projection
PDA	Patent ductusarteriosus

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RVOT Right ventricular outflow tract

TOF Tetrology of fallot

TAPVD Total anomalus pulmonary venous drainage .

PAPVD partial anomalus pulmonary venous drainage

VSD Ventricular septal defect

VR Volume rendered

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Figures titles/ Legands

Figure 1: 20 years male old patient presented by exertional dysnea. PAPVD with two right pulmonary veno-SVC connections representing the segmental tributaries of right superior pulmonary veins. Sinus venosus ASD, superior type, Prominent central pulmonary arteries, Dilated RA and RV.

Figure 2: 12 months old male patient, PAPVD, both superior, middle and inferior pulmonary veins drain into RA, Sinus venosus ASD Dilated RA&RV, Dilated central pulmonary arteries with mild steno sis of the proximal RPA.

Figure 3:22 years old female patient complain of, Truncus arteriosus type I with dilated truncal root and ascending aorta, Cono-truncal VSD, MAPCS.

Figure 4: 2 month old female patient, Atrio-ventricular septal defect (AVSD), Trans-position of the great arteries, Total anomalous pulmonary venous drainage (TAPVD); infra-cardiac type with moderate stenos is of the descending vein, Persistent left SVC, Ostium secondum ASD and small PDA.

Figure 5: 3 weeks old male patient, A case of DORV Fallout type showing, Tight RVOT stenos is with hypo plastic pulmonary annulus & attenuated proximal MPA, Short PDA to proximal LPA with mild steno sis at its pulmonary end, Proximal LPA (pre-ductus)mild stenos is, PFO

.**Figure 6:** 7 months old male patient, DORV /Fallout type with overriding aorta, severe RVOT steno sis, sizable Pas, PFO

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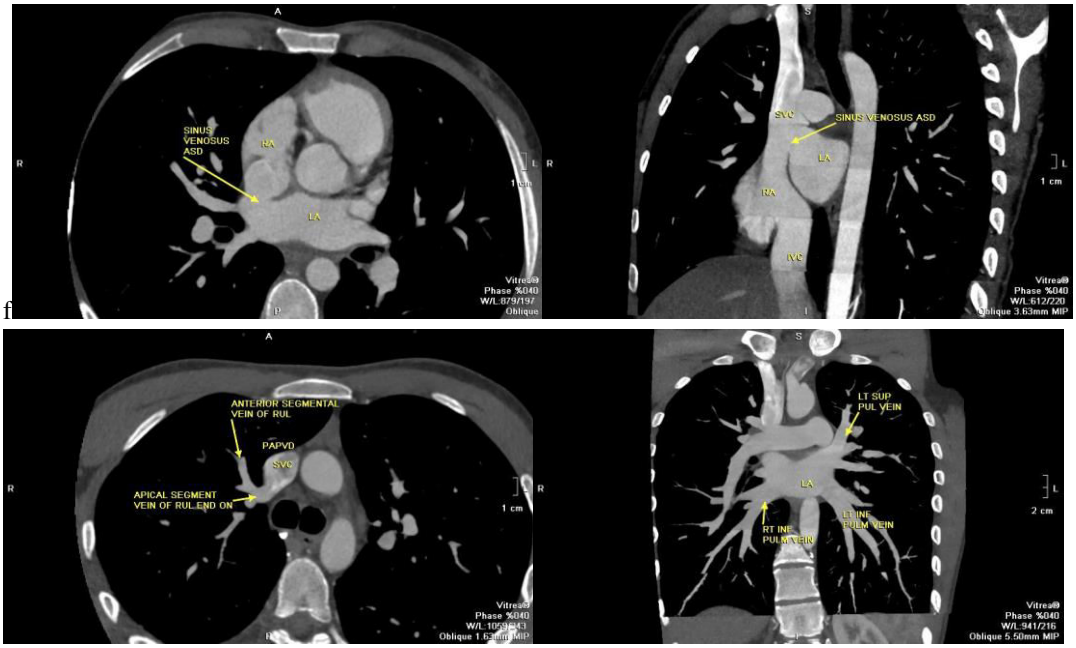

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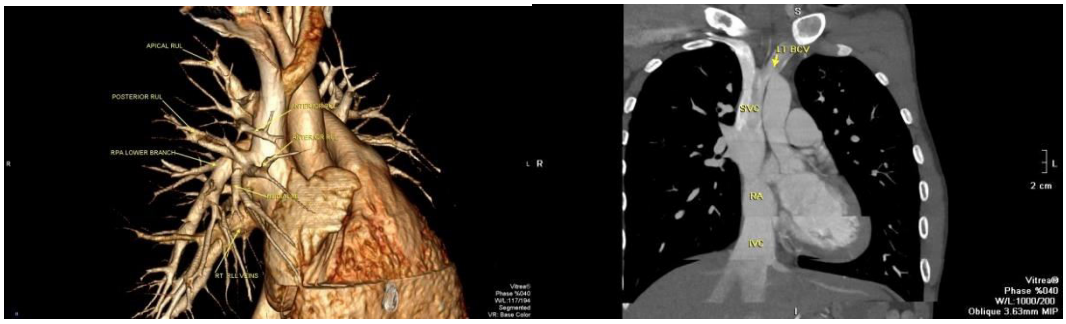
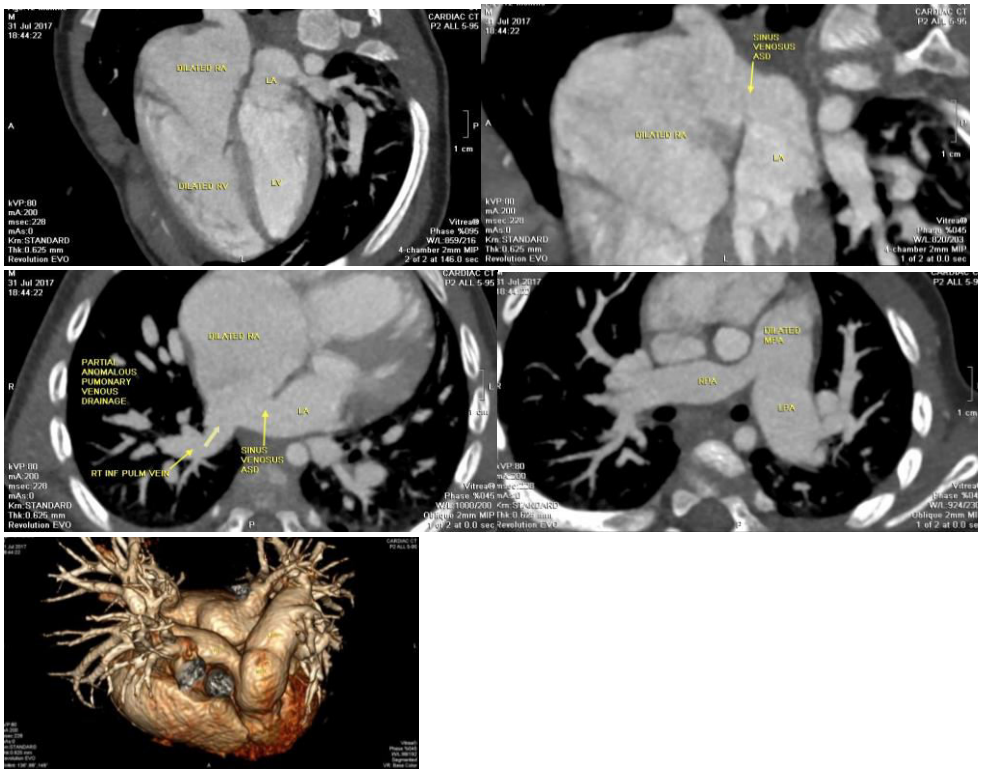


Figure 1



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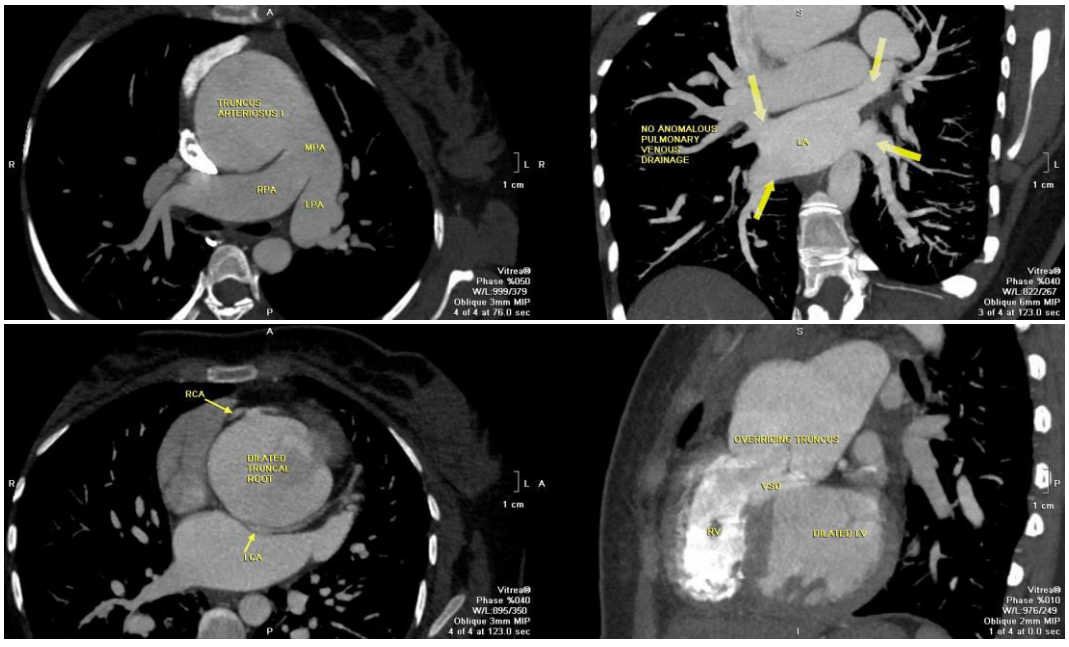

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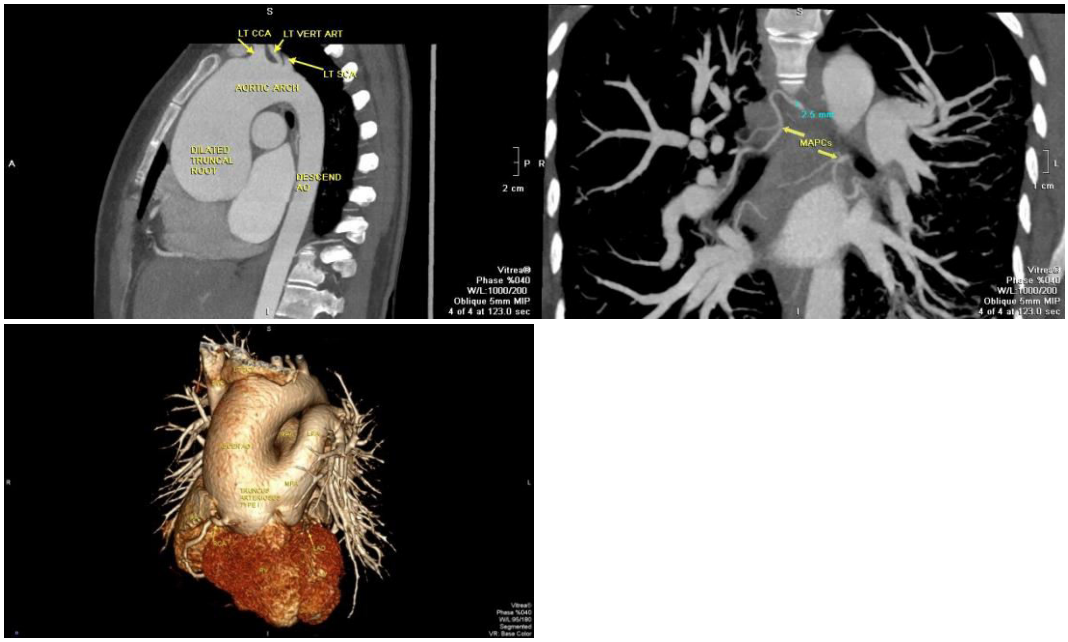

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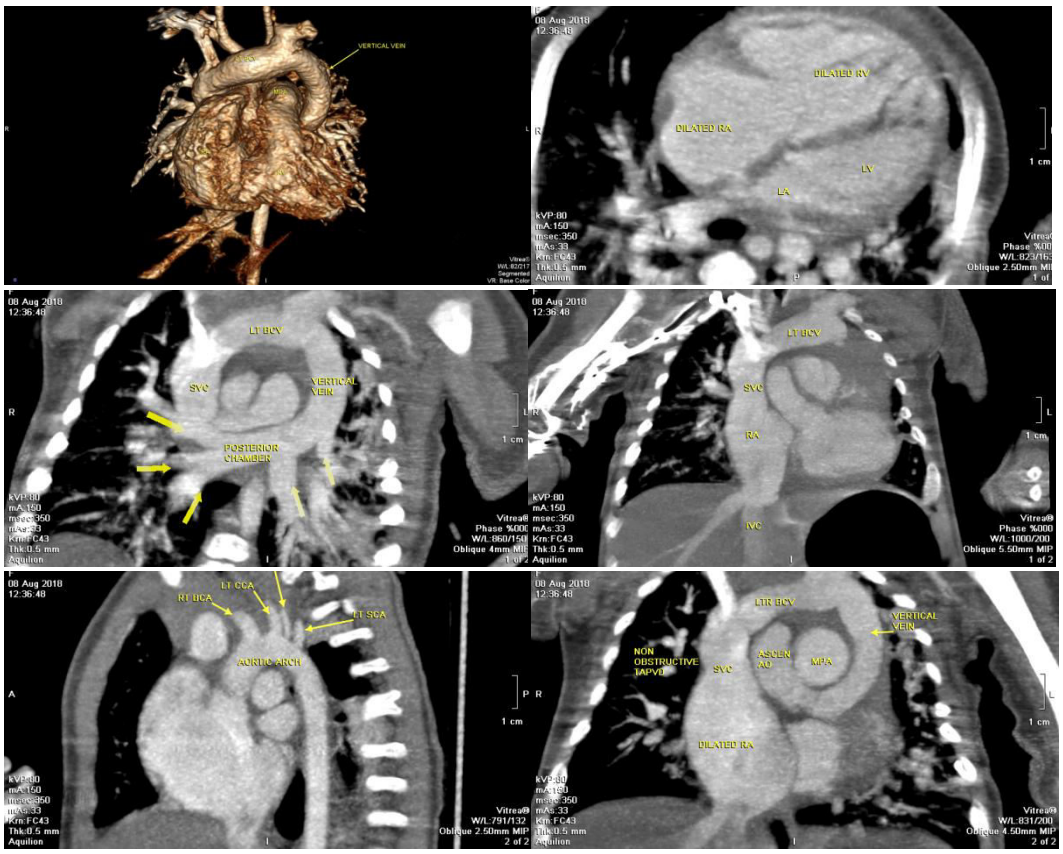

Figure 4

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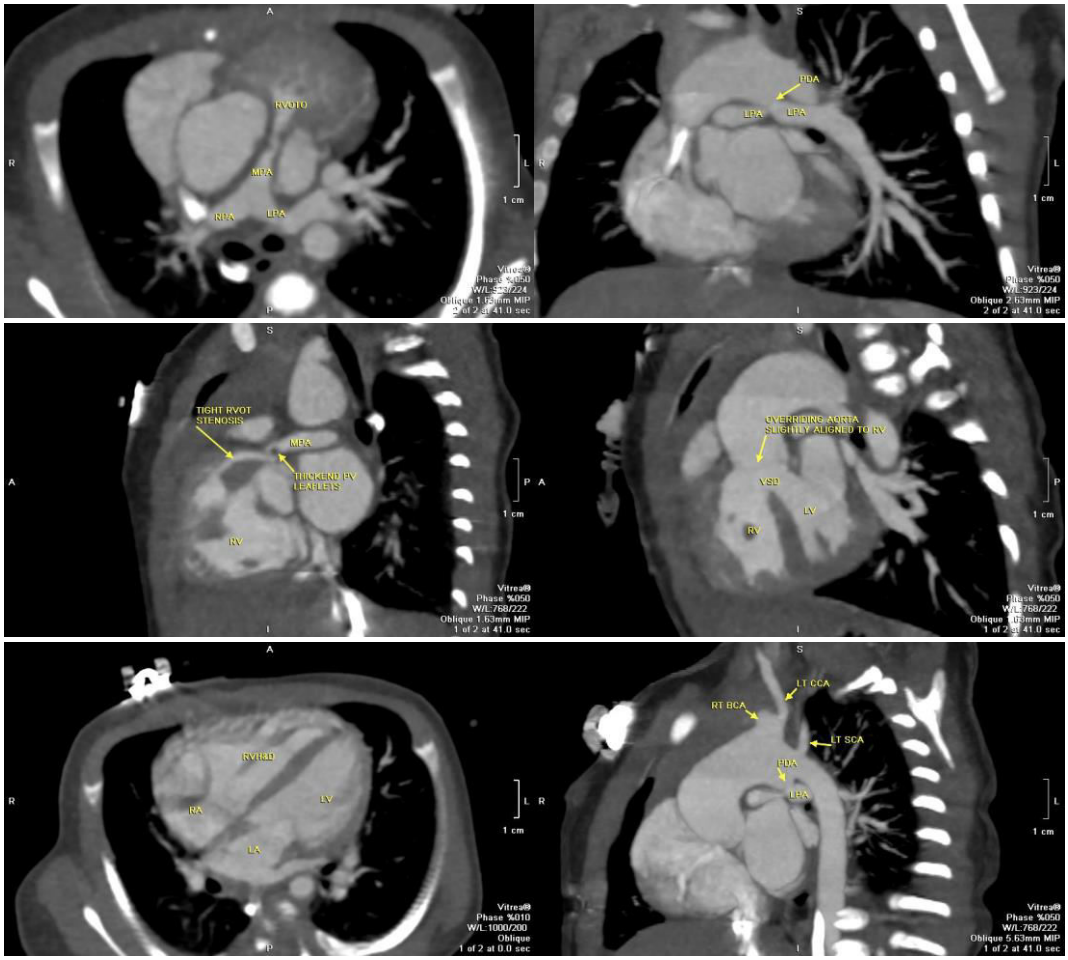
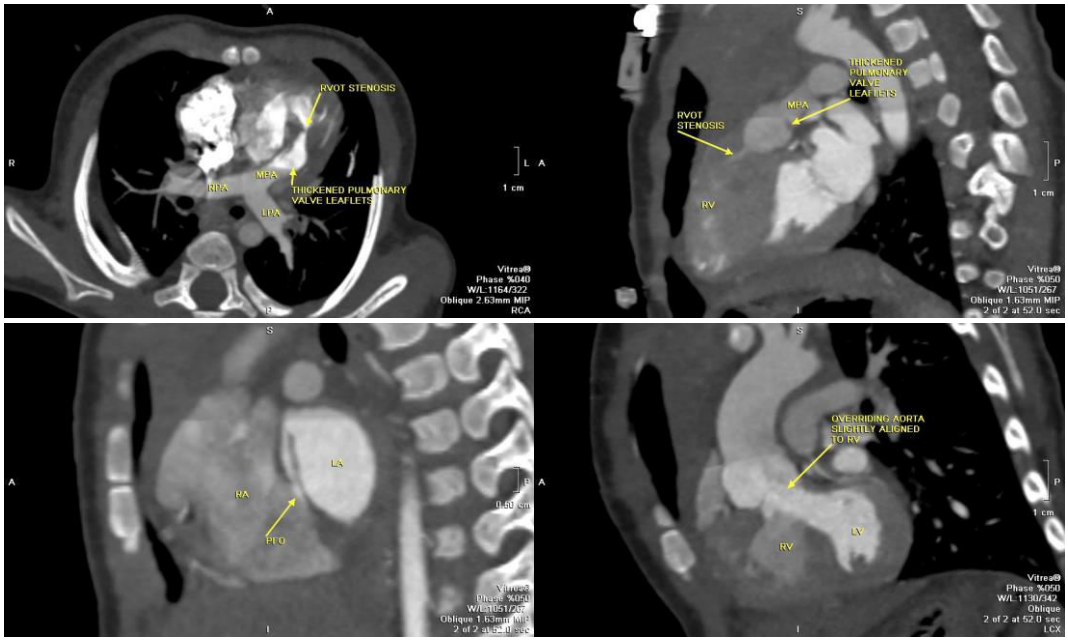


Figure 5



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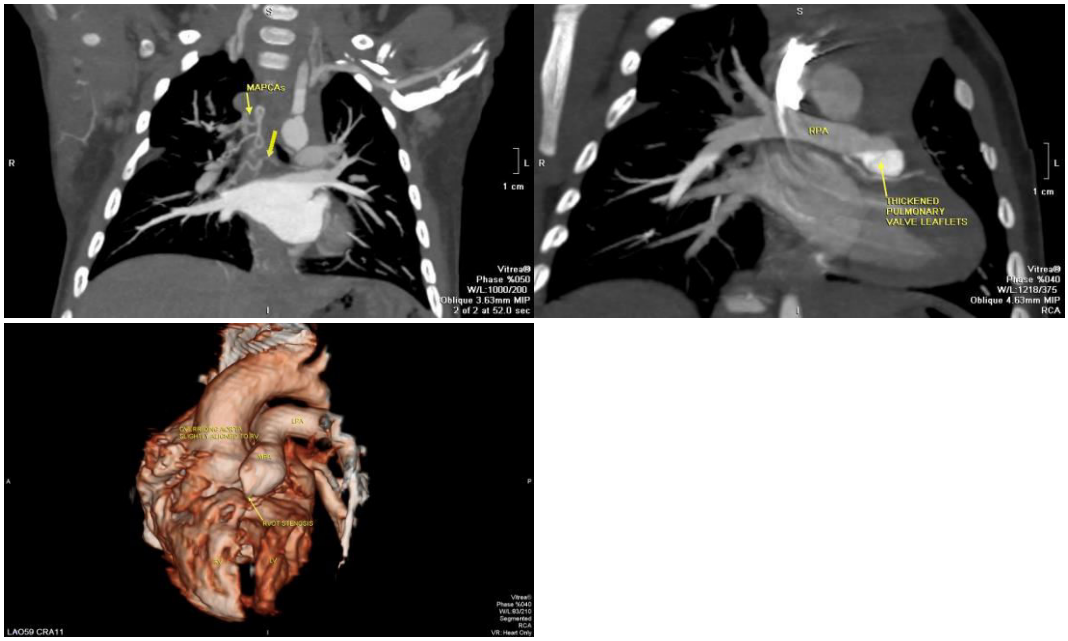

Figure 6