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Value of Multidetector Computed Tomography in Evaluation of Thoracic Venous Abnormalities among Pediatrics with Congenital Heart Disease

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Abstract

Introduction: Venous anomalies of the thorax can involve systemic or pulmonary veins and range from isolated incidental findings to components of more complex anomalies, most often congenital heart disease (CHD). Although echocardiography and catheter directed cardiac angiography are generally accepted as the primary imaging techniques for evaluation of CHD, CT and MRI are important complementary diagnostic tools. Multi-detector computed tomography (MDCT) with its increasing availability and utility is now becoming a further method of imaging CHD. In light of its widespread availability, MDCT and 3D imaging are increasingly considered as a viable "one-stop shop" for preoperative imaging evaluation of cardiovascular structures in selected pediatric patients.

Aim of the work: The aim of this work is to evaluate the role of MDCT in visualization of the thoracic venous system in pediatrics with congenital heart disease, show prevalence and types of venous anomalies and to compare this data with echocardiographic findings.

Methods: The studied group included 30 cases referred to us by pediatric cardiologists to be examined by MSCT angiography of the heart and thoracic vessels. All the patients were known cases of congenital heart disease and underwent echocardiography. They were referred to answer specific anatomic question raised by inconclusive echocardiography, to assess suspected systemic and suspected pulmonary venous anomalies. All patients were subjected to full history taking, clinical examination and MDCT examination with CT lightspeed VCT XT 64-detectors row scanner (General Electric, Medical Systems, Milwaukee, Wisconsin, USA).

Results: CTA findings had 77.8 % concordance with echocardiographic findings regarding SVC anomalies, 66.7 % concordance with echocardiography regarding IVC anomalies and 90 % concordance regarding pulmonary venous anomalies.

Conclusion: Low dose protocol CTA is a promising method that complementary to Echocardioraphy for imaging of extracardiac vascular structures in pediatrics with congenital heart diseases.

Key words: Congenital heart disease. Computed Tomography Angiography. Systemic venous anomalies. Pulmonary venous anomalies.

INTRODUCTION

Anomalies of the heart and the great vessels are mostly present from birth. The majority of such disorders arise from faulty embryogenesis during gestational weeks 3–8, when major cardiovascular structures develop [(1)]. Venous anomalies of the thorax can involve systemic or pulmonary veins and range from isolated incidental findings to components of more complex anomalies, most often congenital heart disease [(2)].

Echocardiography, which can provide both anatomical and functional information, is the mainstay of imaging for evaluating intracardiac lesions in infants and children [(3)]. .In addition to being highly operator dependent, echocardiography may not be sufficient for evaluating extracardiac structures, such as the pulmonary arteries, pulmonary veins, and the aortic arch and great vessels due to acoustic window limitations[(4)].

Cardiac catheterization remains an important component of both anatomical and functional assessment of patients with CHD. However, the clinical decision to precede with such an investigation needs to be balanced with the risks associated with an invasive procedure, which also involves exposure to ionizing radiation [(4)]. Despite the great capabilities of MR imaging for anatomic and functional assessment of the heart, an examination with this modality is time-consuming and may require a lengthy period of patient sedation[(5)].

Multi-detector computed tomography (MDCT) with its increasing availability and utility is now becoming a further method of imaging CHD [(6)].

THE AIM OF THE WORK

The aim of the work is to evaluate the role of MDCT in visualization of the thoracic venous system in pediatrics with congenital heart disease, show prevalence and types of venous anomalies and to compare this data with echocardiographic findings.

METHODS

This study included 30 cases referred by pediatric cardiologists to be examined by MSCT angiography of the heart and thoracic vessels. All the patients were known cases of congenital heart disease and underwent echocardiography. They were referred to answer specific anatomic question raised by inconclusive echocardiography; to assess suspected systemic and suspected pulmonary venous anomalies.

This work was done in cooperation with El-Galaa military family hospital where the scanning was performed from June 2010 to June 2011.

After taking oral consent from all patients to undergo cardiac MDCT angiography. After revision of the patient history, previous investigation and referral sheet, we determined which anatomical part of the circulation is in need for clarification, this allowed determining the site of venous cannulation and the contrast injection rate.

Light sedation using oral chloral hydrate 0.5 ml/kg of body weight for some infants and non cooperative children below the age of 7 years. There was no need for general anesthesia in this study.

Scanning technique:

- All examinations were done using CT lightspeed VCT XT 64-detectors row scanner. Mechanical dual syringe power injector was used for contrast and saline chaser injection. Low osmolar non ionic contrast (ultravist 300, Schering AG, Germany) was injected intravenously in all patients with weight adjusted dose, followed by saline chase.
- A non contrast scanogram (scout) was obtained in 2 planes; anteroposterior and lateral projections.
- Adjustment of the scan parameters to achieve low radiation dose protocol using
Non ECG gated protocol, low tube voltage and current and high pitch.
- Estimation of the contrast coverage time covering the scan delay time and supposed time till proper opacification of the target.
- Estimation of the flow rate of contrast injection relying on the target of the study, body weight and size of the cannula.

Scan the locator image simultaneously with running injection then Scan phase: when the desired enhancement of the vascular structure of interest is reached, pressing the key "scan phase" will start scan after the predetermined scan delay time.

- Intentionally Single phase CT axial cuts were obtained for all cases from the thoracic inlet to the level of L1-L2 vertebrae and the quality of images were reviewed before the examination was terminated.
- Post scanning patient assessment was done.
- By the end of examination, axial images were transferred to the work station (Advantage work station 4.4, GE medical system). Multiplanar reformation (MPR), volume rendering and maximum intensity projection (MIP) images were obtained after editing axial images for all patients. Measurements and annotations for different anatomical part of interest were carried out. More advanced 3D reformatting, volume rendering (VR) reformatted, movie editing and navigation through a lumen, etc were available and done when indicated.

RESULTS

The study included 15 male patients and 15 female patients, male patients were representing 50% and female patients were representing 50 % of the study population. The youngest patient was 2 months old male and oldest was 14 years old male. Mean age was 2 years and 1 month. Minimum body weight was 3 kg for 2 months old male patient and maximum body weight was 30 kg for a 14 years old male patient. Mean body weight was 8.6 kg.

The target of our study was assessment of suspected pulmonary venous anomalies in 20 patients (66.7%) and the assessment of suspected systemic venous anomalies in 12 patients (40%). Two patients had both suspected Pulmonary and systemic venous anomalies. Figure (1)

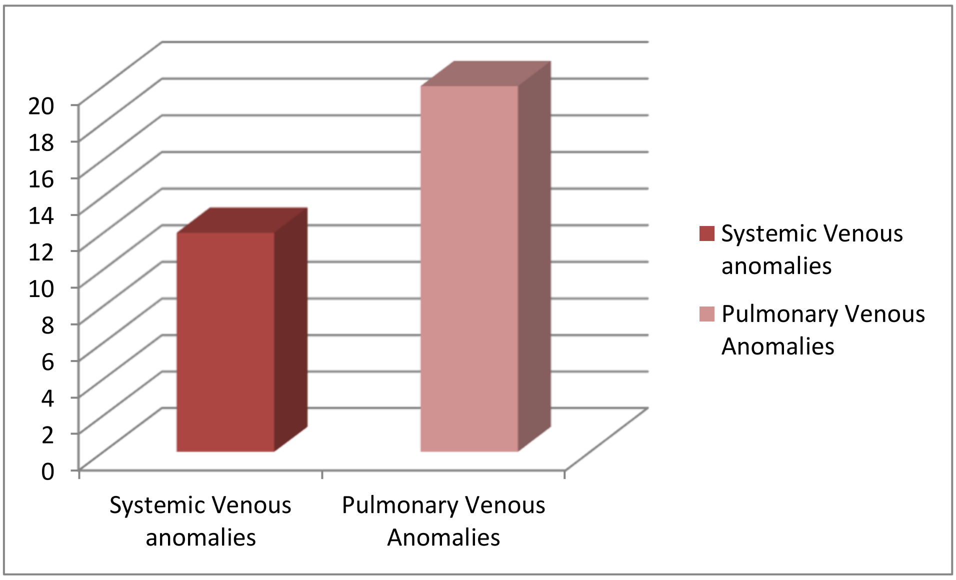

Figure (1): chart shows the distribution of cases according to the target of the scan.

Systemic venous anomalies were the target of MSCT angiography in 12 patients (40%) ; 6 patients were suspected by echocardiography to have Bilateral SVC, 3 cases were suspected to have Interrupted IVC and 3 cases were suspected to have both anomalies.

Table (1) shows the primary diagnosis as well as MDCT findings of the patients with anomalous systemic venous drainage.

Scan target	**Primary diagnosis**	**No.**	**MDCT**
Systemic venous drainage	Suspected bilateral SVC	6	4 confirmed 2 excluded
	Suspected Interrupted IVC	3	1 confirmed 1 excluded 1 inconclusive
	Suspected Bilateral SVC + Interrupted IVC	3	3 confirmed
Total	12 patients (40%)		8 (26%) confirmed 3 excluded 1 inconclusive findings.

Table (2) shows the percentages of concordance and discordance between echocardiography and CTA regarding SVC anomalies:

	Frequency	Percentage	Valid Percent
Concordant	7	23.3	77.8
Discordant	2	6.7	22.2
Total	9	30	100

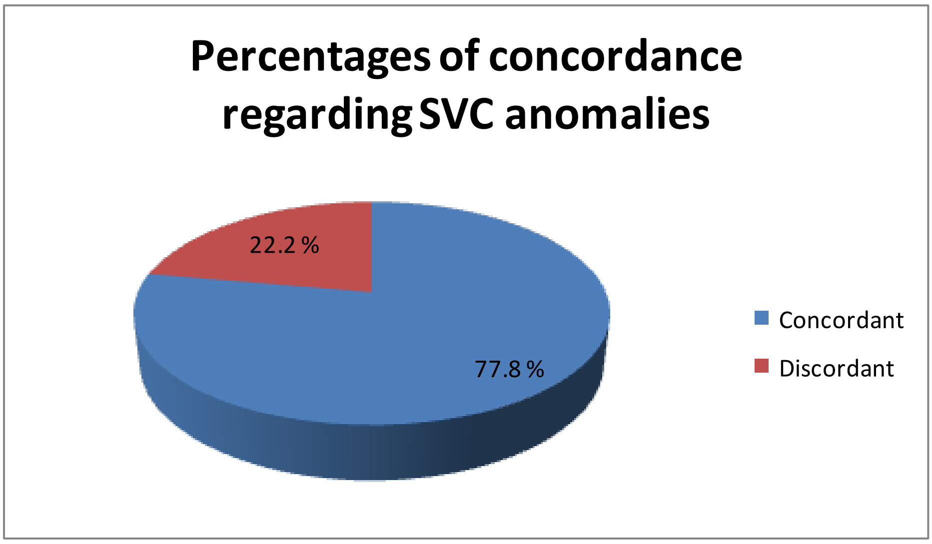

Figure 2: Chart shows the percentage of concordance regarding SVC anomalies.

Table (3) shows the percentages of concordance and discordance between echocardiography and CTA regarding IVC anomalies:

	Frequency	Percentage	Valid percentage
Concordant	4	13.3	66.7
Discordant	1	3.3	16.7
Inconclusive	1	3.3	16.7
Total	6	20	100

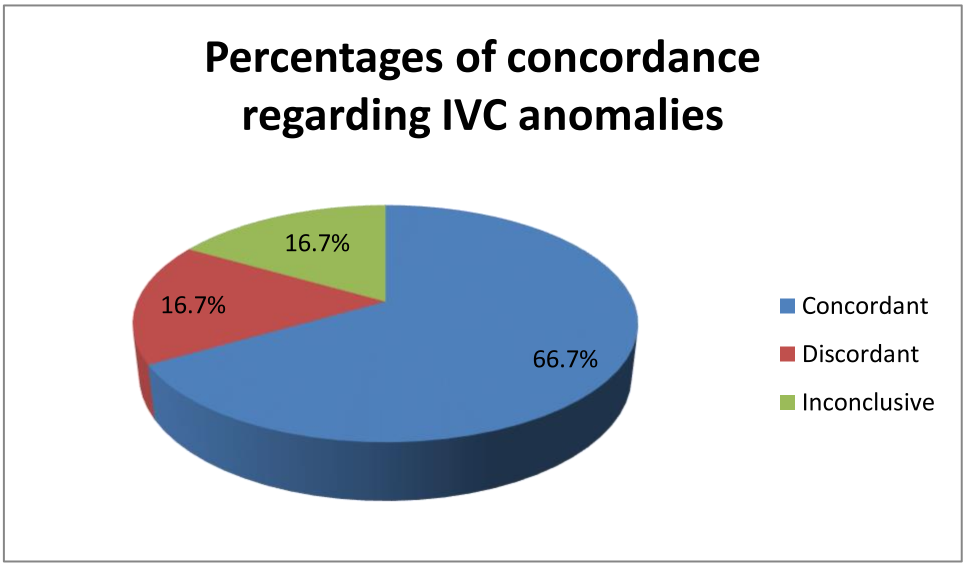

Figure 3: Chart shows the percentage of concordance regarding IVC anomalies.

Table (4) shows the Site of Drainage of Persistent Left SVC

Site of Drainage of Persistent Left SVC (11 cases)	
Coronary Sinus into Right Atrium	7 (64%)
Left atrium	2 (18%)
Opening Could not be assessed	2 (18%)

Table (5) shows the Site of Drainage of Azygous arch in cases of IVC Interruption

Site of Drainage of Azygous arch in cases of IVC Interruption (6 cases)	
Left SVC	2 (33%)
Left atrium	2 (33%)
Right atrium	2 (33%)

Twenty patients (66.7% of the study population) were referred for confirmation or exclusion of anomalous pulmonary venous drainage that were suspected by echocardiographic examination.

Table (4) shows the primary diagnosis as well as MDCT findings of the patients with anomalous pulmonary venous drainage.

Scan target	Echocardiographic impression	No	MDCT
Pulmonary venous drainage	Suspected Anomalous pulmonary venous drainage	20	16 TAPVD 2 PAPVD 2 excluded
Total	20 patients (66.7%)		18 patients (60%)confirmed 2 excluded.

Table (5): Various types of the anomalous pulmonary venous drainage and their incidence among the study population.

Scan finding	**incidence**	**Drainage site**
PAPVD to RA	1/2	1 ; lower right pulmonary vein to RA
PAPVD to LA	1/2	1; Lower right &Lower left pulmonary vein to RA
PAPVD	**2 cases (6 % of the study population)**	

Table (6): Various types of the Total anomalous pulmonary venous drainage and their incidence among the study population.

Scan Findings	Incidence	Drainage site
Cardiac TAPVD	6 (37.5%)	4 to CS 1 to RA 1 to SVC
Supracardiac TAPVD	6 (37.5%)	6; ascending vein to innominate vein
Infracardiac TAPVD	3 (18.5%)	3; Descending vein to portal circulation
Mixed type TAPVD	1 (6.5%)	upper and middle left veins to SVC and 3 right with lower left to obstructed descending vein into hepatic vein.
TAPVD	16 cases (53% of the study population)	
Total	16 TAPVD 2 PAPVD 2 excluded	

Table (7) shows the percentages of concordance and discordance between echocardiography and CTA regarding Pulmonary Venous anomalies.

	Frequency	Percentage	Valid Percent
Concordant	18	60	90
Discordant	2	6.7	10
Total	20	66.7	100

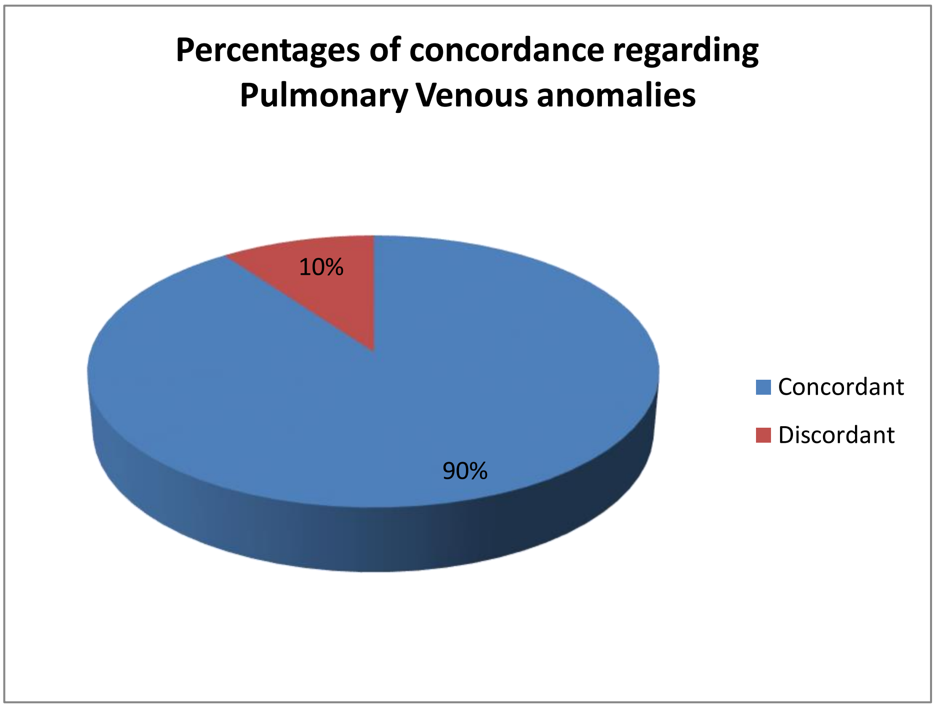

Figure 4: Chart shows the percentage of concordance regarding Pulmonary Venous anomalies anomalies. Good diagnostic image quality made CTA conclusive diagnosis achievable in all cases of SVC anomalies and Pulmonary venous anomalies and in 83% of cases of Interrupted IVC.

DISCUSSION

To achieve a successful surgical operation and catheter intervention in children with congenital heart disease (CHD), accurate anatomical information of the cardiovascular system is essential. However, it is sometimes difficult to understand the real structure of complicated CHD by conventional 2D diagnostic modalities, such as 2-dimensional (2D) echocardiography or angiography, because these anomalous structures are complicated and tortuous [(7)].

CT can be used to evaluate patients with congenital heart disease (CHD) known or suspected on the basis of echocardiographic findings for which further imaging is needed to characterize extracardiac anomalies before intervention. The pulmonary arteries, pulmonary veins, and aortic arch and great vessels may be inadequately characterized at echocardiography, necessitating further assessment with CT [(8)].

The target of our assessment was:

- Suspected Pulmonary venous anomalies in 66.7% of the study population; to confirm and assess the number of anomalous veins and abnormal site of drainage and presence of stenosis through its course.
- Suspected Systemic venous anomalies in 40% of the study population,to assess the number, location and drainage of the SVC, Absence of the intrahepatic IVC and Hepatic venous drainage.
- For accurate diagnosis of normal thoracic venous anatomy and drainage not adequately visualized by echocardiography especially in irritable patients.

When we started this study, we were driven by the impression that CT findings would be more interpretable and more diagnostic than echocardiographic findings in detecting thoracic venous anomalies in children. This impression was supported by the following facts:

- CT images are known to be of better quality with easier differentiation between various structures.

- Contrast enhanced images is an advantage in CT studies, especially when the target is a vascular structure.
- Limited acoustic window and the presence of natural ultrasound barriers such as bone in the chest wall as well as air in the lungs, which can significantly reduce the image quality and hence the diagnostic accuracy.
- Echocardiography is rather operator dependant and is a real time study, which is not the case with the CT study, which can be assessed at any time minimizing the operator dependency.

In the **current Study**, Anomalous Pulmonary venous drainage was the target of MSCT examination in 20 patients (66.7% of the study group); 16 Patients were confirmed by MSCT angiography to have TAPVD representing (53% of the study group), two patients were confirmed to have PAPVD (6% of the study group) and two patients were excluded. This means 90 % concordance and 10 % discordance between echocardiography and CTA. Good diagnostic image quality made CTA conclusive in all cases of pulmonary venous anomalies.

In our study, the 16 cases proved by MSCT to have TAPVR,6 cases of them (37.5 %) were of the supracardiac type, 6 of them (37.5%) were of the cardiac type, 3 of them (18.5 %) were of infracardiac type , and 1 (6.5 %) was of the mixed type ; supracardiac & infracardiac TAPVR . The two cases of PAPVR, 1 of them had anomalous drainage of the left upper pulmonary vein into the left atrium and the other had anomalous drainage of the right lower pulmonary vein into the right atrium.

In a study by **Osama in 2013[9]** on 26 patients suspected or diagnosed of having pulmonary venous anomalies on examination and echocardiography. Pulmonary venous abnormalities were classified into partial (PAPVR) and total (TAPVR) pulmonary venous anomalies with its three subtypes (supracardiac, cardiac and infracardiac). Pulmonary vein stenosis was also included as an abnormality in this study. The most common pulmonary venous anomaly encountered in that study was total anomalous pulmonary venous return (TAPVR) with its three subtypes representing 61% of the cases. The commonest subtype of TAPVR was the supracardiac type accounting for 50% of TAPVR cases.

Echocardiography failed to demonstrate the four cases of infracardiac type of TAPVR. CT angiography was also of great benefit in diagnosing the different types of TAPVR and detecting the site of connection of the common pulmonary vein. The CT also detected associated stenosis in the common pulmonary vein in two of the infracardiac types of TAPVR as it crosses the diaphragm [9].

Six of the cases of PAPVR revealed to be Scimitar syndrome with CT. Echocardiography wrongly diagnosed one case of PAPVR as TAPVR. Agreement between echocardiography and CT in diagnosis of TAPVR was 50%[9] .

Systemic venous anomalies were the target of MSCT angiography in 12 patients (40% of the study population) ; 6 patients were suspected by echocardiography to have Bilateral SVC, 3 cases were suspected to have Interrupted IVC and 3 cases were suspected to have both anomalies.

Regarding the 6 patients suspected to have Bilateral SVC; 4 Patients were confirmed by MSCT angiography to have bilateral SVC, 2 patients were excluded (i.e.: no left SVC). This means 77.8 % concordance and 22.2 % discordance between echocardiography and CTA. Good diagnostic image quality makes CTA conclusive in all cases of SVC anomalies.

Regarding the 3 patients suspected to have Interrupted IVC, 1 Patient was confirmed to have Interrupted IVC, 1 patient was excluded and inconclusive findings were found in 1 patient thus 66.7 % concordance and 16.7 % discordance between echocardiography and CTA findings. Good diagnostic image quality made conclusive diagnosis achievable in 83% of cases of Interrupted IVC.

In a study of 26 patients by **Osama in 2013[9]**, Systemic venous abnormalities detected in the study were classified into left SVC, double SVC and interrupted IVC.The results were two cases of left SVC, two cases of double SVC with no cases of Interrupted IVC. Agreement between echocardiography and CT in diagnosis of Systemic venous abnormalities was 100%.

In 1 out of 30 MDCT examinations (3.3 %) of the **current study**, there were non conclusive findings regarding interrupted IVC in which the CT was not sure of the findings.

Case (1):
Female patient, 4 months old , weighing 4 kg.
Echocardiography impression: Large ASD, Severe valvular PS, Anomalous Pulmonary Venous drainage.
Target of the study: Pulmonary Venous circulation.
MDCT impression: CHD; Supra cardiac non-obstructed total anomalous pulmonary venous drainage, ASD, evidence of valvular PS.

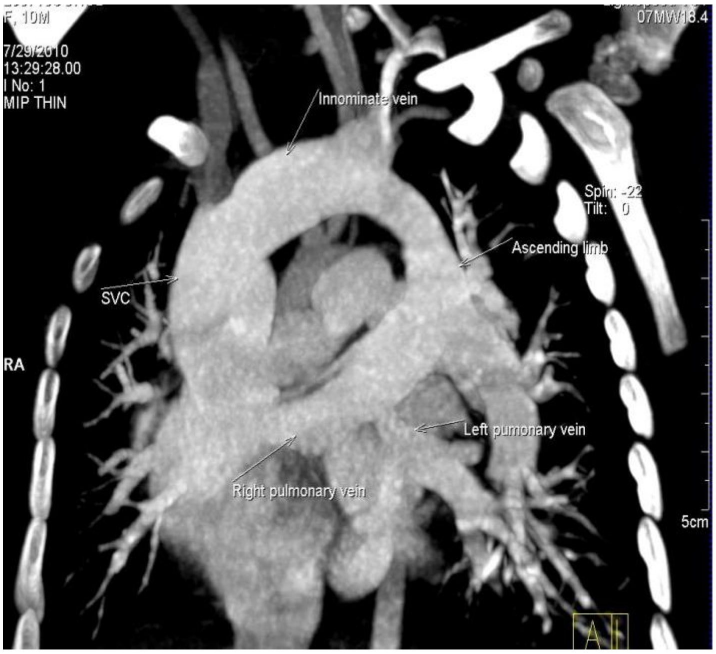

Figure (5): Coronal oblique image shows right and left pulmonary veins draining into a vertical ascending vein into innominate vein to SVC.

Case (2): Female patient, 1 year and 3 months old weighing 7.5 kg.
Echocardiography impression: ASD, VSD,? Bilateral SVC.
Target of the study: Systemic Venous circulation.
MDCT impression: polysplenia, dextrocardia, ASD, VSD, PS, bilateral SVCs (bilateral SVCs both drain into the Lt sided atrium).

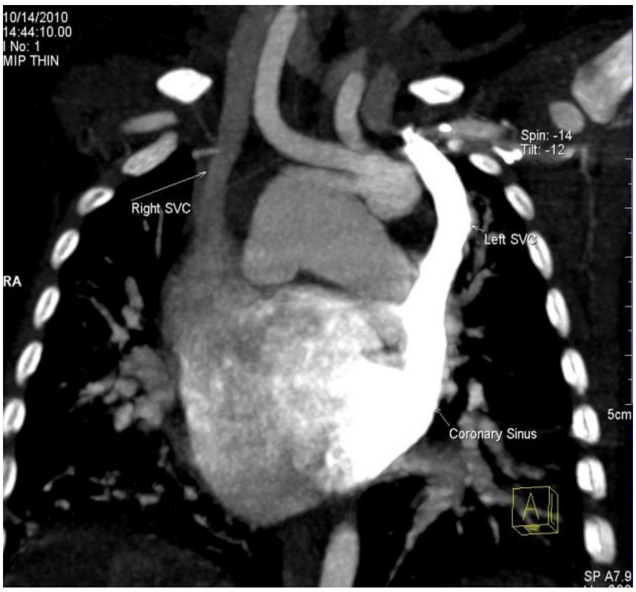

Figure (6): Coronal image shows bilateral SVCs, the left SVC drains into coronary Sinus.

CONCLUSION

The primary role of CT is noninvasive assessment of extracardiac systemic and pulmonary arterial and venous structures and post-treatment complications, most often as an adjunct to echocardiography. Although CT is performed with ionizing radiation, a variety of imaging parameters can be adjusted to minimize radiation exposure of children and maintain image quality.

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