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Don’t Miss What Is Hidden On Cardiac CT Angiography: Extra-Cardiac Findings Count

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Don’t Miss What Is Hidden On Cardiac CT Angiography: Extra-Cardiac Findings Count

Cover Page Footnote

We are grateful to our patients who accepted to participate in our study

ORIGINAL STUDY

Do Not Miss What is Hidden on Cardiac Computed Tomography Angiography: Extra-cardiac Findings Count

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Abstract

Background: **Multi-detector computed tomography (MDCT)is the main imaging modality in cardiovascular diseases. Another important role of MDCT is assessment of extra-cardiac structures outside the pericardium. These extra-cardiac findings may be of great relevance.**

Methods: **Cardiac MDCT scan results were retrospectively reviewed by radiologist for the presence of extra-cardiac findings between February 2020 and December 2022. They were categorized according to anatomical location into systems as pulmonary, pleural, mediastinal, bronchial, vascular, bony, abdominal and miscellaneous.**

Results: **A total of 955 patients had a cardiac multidetector CT angiography scan during the study period. Extra-cardiac findings were reported in 320 (33.5 %) of these 192 (60 %) were males, 182 (56.8 %) were less than 1-year age, while 7 (2.1 %) were more than 18 years' age. They were categorized by systems (airway, pulmonary, abdomen, malpositioned lines and bony). Then we sub-classified these findings by level of clinical importance based upon the need for intervention or treatment into clinically significant and non-significant findings. The most common locations of extracardiac findings were chest (75.9 %; 243/320), followed by abdominal (11.5 %; 37/320), bony (4.6 %; 15/320), post-operative (4.06 %; 13/320) and vascular (0.9 %; 3/320). The most common abnormalities were pulmonary consolidations (145 out of 320 patients).**

Conclusions: **Extra-cardiac findings are common in patients undergoing cardiac multidetector CT, with a percentage of unexpected significant extracardiac findings about 73 %. Adequate tailored evaluation of all structures in the field of view should be performed by pediatric radiology and cardiac imaging expertise to ensure urgent interventions can be undertaken when necessary.**

Keywords: Extra-cardiac, Cardiac CT, Congenital, Heart

1. Introduction

Multi-detector computed tomography (MDCT) is the gold standard noninvasive imaging modality in cardiovascular disease imaging in both pediatrics and adults in many indications such as congenital heart diseases (Kay et al., 2019).

It also can be used for the assessment of coronary arteries as a part of acute chest pain protocol and planning before some interventional procedures like catheterization in aortic valve replacement and atrial fibrillation (Simon et al., 2022).

Another important role of MDCT is an assessment of extracardiac structures outside the pericardium which can be missed (Kay et al., 2019).

These extracardiac findings may be unexpected and of great relevance. Analysis of these findings may reveal significant findings that can enable early diagnosis of significant but clinically silent problems which can affect the outcome of the treatment protocol (Mantini et al., 2019).

Abbreviations: MDCT, Multi-detector computerized tomography; ECF, Extracardiac findings; SECF, Significant extracardiac findings; NECF, Nonsignificant extracardiac findings; CPSS, congenital porto-systemic shunt.

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The extracardiac findings are most commonly detected in the lung parenchyma, mediastinum, abdomen or in the vessels (Karius et al., 2014).

The new generations of computed tomography (CT) machines with lower radiation doses have resulted in performing countless numbers of cardiac CT scans which detect multiple of extracardiac variants and pathology (Sassoon et al., 2023).

2. Aim

The aim of the study is to highlight the numerosity and diversity of extracardiac findings that could be detected on cardiac CT angiography (CTA), which could be clinically significant and could affect the patients' prognosis in many circumstances.

2.1. Methods

This study was approved by our institutional research board. Informed consent was waived because of the retrospective nature of the study.

For this study 955 cardiac CT reports were reviewed for the period from February 2020 to December 2022 for scanning for noncardiac findings. For patients with multiple reports only one report was evaluated and repeated examinations were excluded. Also, reports with findings as pulmonary atelectatic bands were excluded as they were found to be very common and thought to be clinically irrelevant and extra cardiac findings coping with heterotaxy were excluded also; as anomalies of the location or the appearance of certain organs is among their components were excluded. So, out of them we found extracardiac findings in 320 (33.5 %) reports (192 males, 128 females), their ages were grouped into groups less than 1 year (number = 182), groups with age ranging from a year to less than or equals 9 years (number = 95), group with age ranging from more than 9 years to less than or equals 18 years (number = 36), the last group with age more than 18 years (number = 7).

Cardiac MDCTs were reported by consultants' radiologists with cardiac imaging experience and an average of 10 years of experience.

Cardiac MDCT was done using a multi-detector CT scanner (Philips Ingenuity Core 128, Philips Healthcare, the Netherlands) for patients with proved or suspected congenital heart disease and/or arrhythmia. The field of view extended from the base of the neck to the upper abdomen. Retrospective ECG-gating was used. The examination was done in a supine position. Prior to the examination, the patients were informed to fast for 6–8 h. Injection of intravenous contrast agent using automatic injector at a dose of 1–2 ml/kg.

The findings were numerous, so they were grouped according to their location as, chest findings; were regrouped as pulmonary, pleural, mediastinal and abdominal findings; then regrouped according to related organs as liver, spleen, pancreas, kidney, bony (chest wall, ribs, vertebral), and postoperative (iatrogenic) related; sternotomy related, misplaced tubes and miscellaneous (discussed clearly at Table 3).

Then these findings were categorized as clinically significant and clinically non-significant according to its effect on the prognosis of the disease and its effect in the patients' morbidity and mortality.

2.2. Statistical analysis

Continuous variables will be presented as mean +/−standard deviation (SD) when normally distributed and as median and range when non normally distributed. Categorical variables (ordinal and nominal) will be presented as frequency and percentage.

Comparison between two groups will be done by student's *t*-test for normally distributed continuous variables and by Mann–Whitney foe continuous variables when non-normally distribution. Comparison between two groups will be carried out by χ^2 test or fisher exact test as appropriate. B-Value less than 0.04 will be considered as cut-off value of significance. SBSS program version 22 (California, USA) will be used for storage and analysis of data.

3. Results

Our study included 320 patients (192 males,128 females). We had a wide range of ages varying from 2 days old to 62 years (Table 1).

Miscellaneous diversity of various diagnoses was presented in our study where different organs were inspected for extracardiac findings (ECF) systematically. ECFs were then classified into significant

Table 1. Patients' demographics in patients with different extracardiac findings.

Demographics	Number of patients (%)
Sex	
Male	192/320 (60 %)
Female	128/320 (40 %)
Age	
<1 year	182/320 (56.8 %)
1-<9 years	95/320 (29.6 %)
9-< 18 years	36/320 (11.25 %)
>18 years	7/320 (2.1 %)

(SECF) and nonsignificant (NECF) (Table 2). A total of 438 findings were exhibited in 320 patients. This discrepancy is attributed to the presence of more than one finding in some of the patients. Out of these 438 findings, 319 of them were SECF while 119 were clinically insignificant extracardiac findings.

Regarding chest findings, we looked for pulmonary, bronchial, pleural, tracheal, and pericardial changes, where they collectively represented (75.9 %) of our 320 patients. The most prevalent of these changes was consolidation (either unilateral (Fig. 1b) or bilateral), existing in 145 patients out of total 243 patients who showed significant extracardiac chest findings (Table 3). Moving to the abdomen, organs were inspected for anomalies, masses, hernias, and other findings as listed in (Table 3). Significant abdominal changes represented (11.5 %) of the detected abdominal changes. The most frequent significant finding was congested liver ($n = 7$). Other captivating abdominal extracardiac findings included hemangioendothelioma (Fig. 2a) ($n = 1$) and another showing periportal fibrosis ($n = 1$). On the other hand, the most common nonsignificant abdominal ECFs were splenules ($n = 13$) and hepatic hemangiomas ($n = 10$). Some patients displayed masses as incidental findings for the first time during their Cardiac CT scan. Cystic hygroma (Fig. 4b) ($n = 1$), gastric mass ($n = 1$), suprarenal mass ($n = 1$), mediastinal hemangioma (Fig. 1a) ($n = 1$), amalgamated mediastinal nodal mass ($n = 1$). Other post-intervention significant findings were also reported, endotracheal tube was misplaced in one patient into the right main bronchus ($n = 1$).

The skeletal system was not missing for incidental findings either. We reported variable skeletal findings ($n = 38$). Out of which, significant findings were represented in 4.6 % of them ($n = 15$). These changes included vertebral findings ($n = 3$), chest wall and ribs ($n = 12$). In the matter of vascular findings, 35 patients showed a wide diversity of findings. Despite the very infrequent number of patients with significant vascular findings, three patients were reported for interesting vascular findings, thrombosed umbilical vein (Fig. 3c) ($n = 1$), congenital porto-systemic shunt (CPSS) (Fig. 3b) ($n = 1$), dilated mediastinal venous collaterals ($n = 1$).

Operated patients who showed postoperative related extracardiac changes ($n = 13$), demonstrated changes as broken wire (Fig. 4a), collections, as well as posterior displacement of the sternum.

4. Discussion

This study showed that paying attention to extracardiac findings on a routine pre or post-operative ECG-gated cardiac CT angiography is of paramount importance. In our study, a considerable number of variable associated findings were delineated. Of these findings, some required close clinical and pathological attention as these findings are mainly not related to the original pathology, however considering that the congenital heart diseases are debilitating and could lead to poor patient's general condition as well as the patient's immunity it is expected to have higher incidence of associated findings representing infections and inflammatory

Table 2. Diagnosis of patients having significant and nonsignificant extracardiac findings (ECF).

	Associated significant extracardiac findings No. patients (%)	Associated nonsignificant extracardiac findings No. patients (%)
Diagnosis		
Structurally normal heart	13/320 (4.1 %)	8/320 (2.5 %)
Tetralogy of Fallot	24/320 (7.5 %)	24/320 (7.5 %)
Double outlet right ventricle	13/320 (4.1 %)	5/320 (1.6 %)
Double inlet left ventricle	1/320 (0.3 %)	1/320 (0.3 %)
Transposition of the great vessels	17/320 (5.3 %)	12/320 (3.75 %)
Right chamber atresia or stenosis	7/320 (2.2 %)	5/320 (1.6 %)
Hypoplastic left heart syndrome.	3/320 (0.9 %)	0/320 (0.0 %)
Truncus arteriosus	9/320 (2.8 %)	3/320 (0.9 %)
Intra/Extracardiac shunts	44/320 (13.75 %)	13/320 (4.1 %)
Coarctation	18/320 (5.6 %)	7/320 (2.2 %)
Interrupted AA and AA anomalies	9/320 (2.8 %)	3/320 (0.9 %)
Anomalous venous return	8/320 (2.5 %)	2/320 (0.6 %)
Williams syndrome	2/320 (0.6 %)	2/320 (0.6 %)
Combined anomalies	25/320 (7.8 %)	9/320 (2.9 %)
Others	21/320 (6.6 %)	12/320 (3.75 %)
Operated	41/320 (12.8 %)	38/320 (11.8 %)
Not Operated	173/320 (54.1 %)	68/320 (21.25 %)

AA, aortic arch.

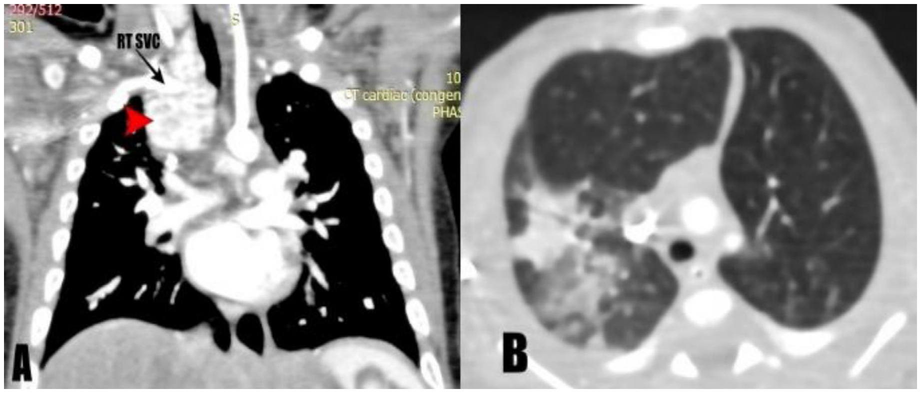

Fig. 1. Example of Chest findings: (a) Coronal reformatted multi-slice computed tomography image shows a well-defined enhancing mass (red arrowhead) at the right side of the lower neck extending to right side of the middle mediastinum compressing the right lateral tracheal wall and totally encasing the right subclavian artery (RT SCA). Pathologically proven mediastinal hemangioma. (b) One month old patient presented with tricuspid atresia, axial multi-slice computed tomography shows few patches of consolidation at the right upper lung lobe associated with area of ground glass densities. MSCT: multi-slice computed tomography, RT SCA: right subclavian artery.

conditions. Theses extracardiac findings can affect the patient's management in many ways as delaying preplanned cardiac operation or undergoing further investigation to confirm the pathological nature of the accidental extracardiac findings and assessing its effect on the patient's life expectancy.

Finally the patient received the proper care and treatment. Missing a clinically significant extracardiac finding can lead to dramatic deterioration of the patient. Our study emphasizes the necessity of heeding these findings.

Multi detector cardiac CT has surfaced as a beneficial diagnostic tool in pre and postoperative assessment of various congenital heart diseases. The information offered from multidetector CT imaging creates fundamentals for management and follow-up plans. Unlike echocardiography and MRI, CT is not limited by a small acoustic window or metallic devices (Mazur et al., 2013).

This study illustrates that patients with intra or extracardiac shunts were most associated with SECF. Patients diagnosed as Tetrology of Fallot (TOF) were next common for showing significant ECF.

Regarding incidence of ECF in the nonoperated versus operated ones, ECF were more frequently encountered in non-operated patients. This is maybe owing to the lower number of operated patients in our study.

In the present study, 320 (33.5 %) patients out of 955 Cardiac CTA scans showed extracardiac findings. Significant noncardiac findings that required clinical or radiological follow-up were observed in (42 %) of the patients according to Simon et al. (2022). While, our study identified significant noncardiac findings in 214 (66.9 %) patients. The prevalence of noncardiovascular anomalies was 58 % in a study conducted by Nordjoe et al. (2022) In other similar studies using CT angiography as the examination technique, this occurrence was 83 % in the study by Malik et al. (2019) 21 and 31.6 % in the study by Rodriguez Martin et al. (Martin et al., 2019) Nordjoe et al. (2022) attributed discrepancy in incidence to the type of MDCT. We don't agree to this hypothesis as our machine was 128-channel MDCT versus 16-channel and 64-channel machines in the stated previous studies. Population demographics and ethnicity may play a role in incidence of such findings.

We looked for chest, abdomen, musculoskeletal and postoperative findings. Chest findings were most frequently demonstrated in our cases. This conforms with Simon et al. (2022), who reported that the lung findings were the most commonly detected in his study as well. Various chest findings were detected in this study including pulmonary, pleural, bronchial, tracheal and pericardial changes. Some of them were of clinical significance needing further investigations and follow-ups. These included consolidations, cases with CORADs four category, infection, pulmonary edema, and vascular malformation. In addition, there were cases exhibiting septic emboli and diffuse lung disease. In our study, the most common lung affection was consolidation, presented in (59 %) of the patients. In contrast to another study by Sassoon, D. J et al. (Sassoon et al., 2023) who reported that atelectasis was the most common lung findings, this is owing to the fact that we excluded the atelectatic bands from our study.

As to abdominal findings, extracardiac abdominal findings were reported in including hepatic, biliary, renal and diaphragmatic findings. Diverse hepatic

Table 3. Significant and nonsignificant extracardiac changes as detected in different body parts.

Findings	SNCF	No of patients (%)	NSNCF	No of patients (%)
Chest	***Total (243/320)***	***243/320 (75.9 %)***	***Total (25/320)***	***25/320 (7.8 %)***
	Consolidation	***145/243 (59 %)***		
			Pulmonary changes	***25/320 (7.8 %)***
	Pulmonary changes	***44/243 (18.1 %)***		
	GGO	10/44 (22.7 %)	Pulmonary nodule	1/25 (4 %)
	CORADS 4	3/44 (6.8 %)	Emphysema	24 (96 %)
	Endobronchial infection	3/44 (6.8 %)		
	Bronchiactasis	3/44 (6.8 %)		
	Congestion/edema	5/44 (11.4 %)		
	AVM	3/44 (6.8 %)		
	Sequestration	5/44 (11.4 %)		
	Septic emboli	3/44 (6.8 %)		
	Diffuse lung disease	5/44 (11.4 %)		
	Pulmonary nodule	2/44 (4.5 %)		
	CCAM	2/44 (4.5 %)		
	Pleural changes	***23/243 (9.5 %)***		
	Bronchial changes	***13/243 (5.3 %)***		
	Tracheal changes	***13/243 (5.3 %)***		
	Pericardial changes	***5/243 (2.06 %)***		
Abdominal	***Total (37/320)***	***37/320 (11.5 %)***		***39/320 (12.2 %)***
	Liver changes	7/37 (18.9 %)	**Liver changes**	
	Congested liver	4/37 (10.8 %)	Fatty deposition	7 (17.9 %)
	Disturbed perfusion	1/37 (2.7 %)	Cyst	2 (5.1 %)
	Hemangioendothelioma	1/37 (2.7 %)	Hemangioma	10 (25.6 %)
	Periportal fibrosis			
	Biliary Changes			
	Dilatation	2 (5.4 %)		
	Pneumobilia	2 (5.4 %)		
	Choledochal cyst	1 (2.7 %)		
			Splenic changes	
			Cyst	1 (2.5 %)
			Hemangioma	3 (7.7 %)
			Splenule	13 (33.3 %)
			Polysplenia	2 (5.1 %)
	Renal Changes		Lobulated spleen	1 (2.5 %)
	Ectopic pelvic kidney	4 (10.8 %)		
	Horseshoe kidney	3 (8.1 %)		
	PUJO	2 (5.4 %)		
	Area of infarction	1 (2.7 %)		
	Diaphragmatic Changes			
	Morgagni hernia	5 (13.5 %)		
	Boghdalek hernia	2 (5.4 %)		
	Hiatus hernia	1 (2.7 %)		
	Eventration	1 (2.7 %)		

(*continued on next page*)

Table 3. (continued)

Findings	SNCF	No of patients (%)	NSNCF	No of patients (%)
Bony	***Total***	***15/320 (4.6 %)***	***Total***	***23/320 (7.1 %)***
	Chest wall and ribs			
	Deficient ribs	2/15 (13.3 %)		
	Fused ribs	5/15 (3.3 %)		
	Deficient and fused	2/15 (13.3 %)		
	Pectus carinatum	1/15 (6.6 %)		
	Reduced AP	1/15 (6.6 %)		
	diameter/slanting ribs	1/15 (6.6 %)		
	Vertebral		**Vertebral**	
	Butterfly, hemivertebra and fused (All combined)	2/15 (13.3 %)	Hemivertebra	6/23 (26.1 %)
	Sacral agenesis	1/15 (6.6 %)	Butterfly vertebra	4/23 (17.4 %)
			Butterfly and hemivertebra	3/23 (13.04 %)
			fused	2/23 (8.7 %)
			Scoliosis	7/23 (30.4 %)
			Hemangioma	1/23 (4.3 %)
Vascular	***Total***	***3/320 (0.9 %)***	***Total***	***17/320 (5.3 %)***
	Venous	1 (0.3 %)	**Venous**	3/17 (17.6 %)
	Thrombosed umbilical V	1 (0.3 %)	Nutcracker	
	CPSS	1 (0.3 %)	**Arterial**	
	Dilated mediastinal venous collaterals		HA or AHA arising from SMA	8/17 (47 %)
			LGA from AO	1/17 (5.8 %)
			CHA gives HA proper, LHA from celiac trunk/RHA from SMA	2/17 (11.7 %)
			SMA from celiac trunk	2/17 (11.7 %)
			Accessory Rt renal artery from Ao at CA level	1/17 (5.8 %)
Nodal			**Nodal**	***Total (15/320) (4.6 %)***
			Mediastinal	9/15 (60 %)
			Hilar	3/15 (20 %)
			Axillary	3/15 (20 %)
Postoperative	***Total***	***13/320 (4.06 %)***		
	Broken wire	5/9 (55.6 %)		
	Gapping	6/9 (66.6 %)		
	Collection	1/9 (11.1 %)		
	Posterior displacement of the sternum	1/9 (11.1 %)		
		1/9 (11.1 %)		

AHA, anomalous hepatic artery; AO, aorta; AVM, arterio-venous malformation; CA, Celiac artery. CCAM, Congenital pulmonary airway malformations; CHA, common hepatic artery; CPSS, congenital Porto-systemic shunt; GGO, grains glass opacity, CORADS:COVID-19 reporting and data system; HA, hepatic artery; LGA, left gastric artery; LHA, left hepatic artery; NSNCF, non significant non cardiac findings; PUJO, pelviabdominal–ureteric junction obstructions; RHA, right hepatic artery; Rt, right; SMA, superior mesenteric artery; SNCF, significant non cardiac findings.

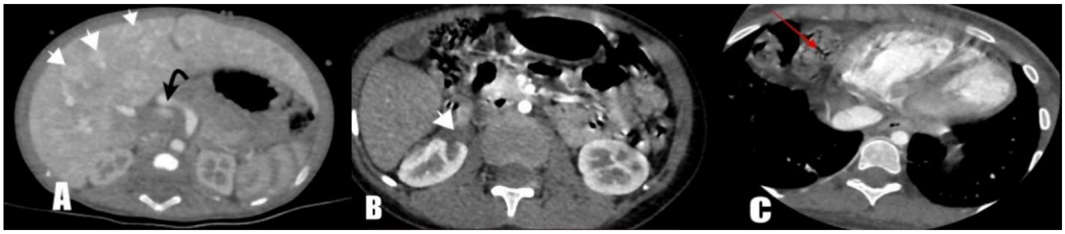

Fig. 2. Example of Abdominal findings: (a) A 6 month male patient with persistent pulmonary hypertension, axial multi-slice computed tomography scan of the abdomen shows multiple enhancing hepatic focal lesions (arrowheads) associated with dilated intrahepatic vessels, dilated hepatic artery (curved black arrow) and dilated celiac trunk. Pathologically proven hemangioendothelioma. (b) A well-defined peripheral edge shaped area in the right kidney (arrowhead) impressive of renal infarction. (c) Axial multi-slice computed tomography showing a large Morgagni hernia with herniated intestinal loops (red arrow) into the right hemithorax. MSCT: multi-slice computed tomography.

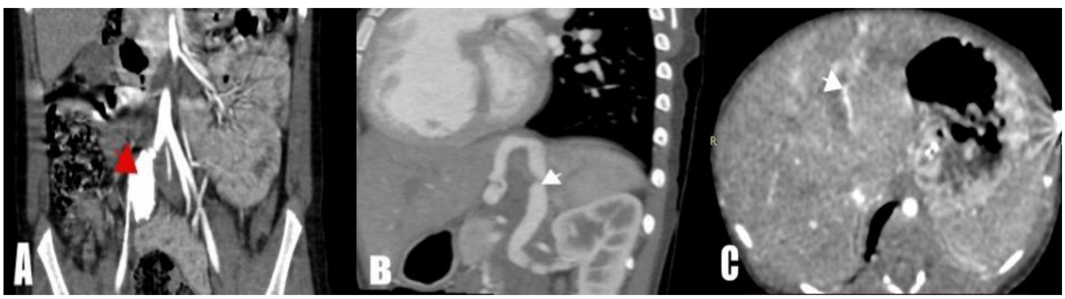

Fig. 3. Example of Vascular findings: (a) Coronal reformatted multi-slice computed tomography image showing a well-defined fusiform aneurysm in the right common iliac artery (arrowhead) extending to its bifurcation, note that right internal iliac artery is occluded. (b) a- 5 years old patient presented with severe Tricuspid regurgitation (TR) and severe pulmonary hypertension, Sagittal oblique reformatted multi-slice computed tomography shows dilated tortuous venous channel (arrowhead) from proximal portal vein to left renal vein, suggestive of type 2 extracardiac congenital portosystemic shunt (CPSS). (c) A 2-month-old patient presented with pulmonary atresia, axial multi-slice computed tomography shows a marginally enhancing track along the course of umbilical vein with noted hypodensity inside (arrowhead) impressive of umbilical vein thrombosis. MSCT: multi-slice computed tomography, TR: tricuspid regurgitation and CPSS: congenital portosystemic shunt.

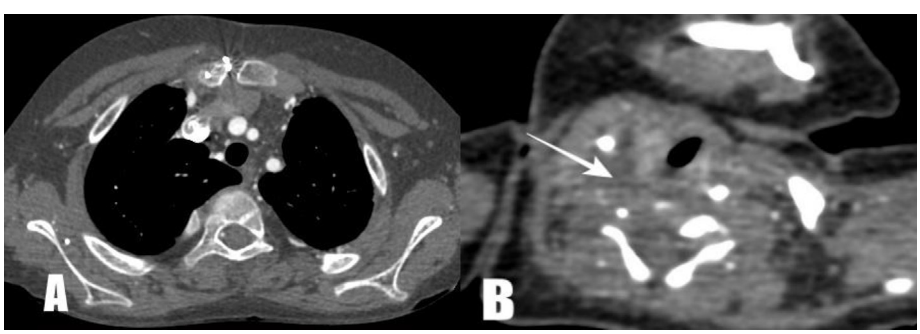

Fig. 4. Others: (a) a 7-years old patient referred for ECG-gated cardiac CT post bidirectional shunt for tricuspid atresia (TA), sternotomy in axial multi-slice computed tomography shows gapping and displacement within manubrium stern. Note the intact wires with broken lowermost wire. (b) A 1-month-old patient referred for ECG gated cardiac CT for right lung agenesis, axial multi-slice computed tomography shows right parapharyngeal collection. Pathologically proven right sided cystic hygroma. CT: computed tomography, MSCT: multi-slice computed tomography and TA: tricuspid atresia.

findings were demonstrated. The most encountered significant hepatic finding was liver congestion representing (18.9 %). Other significant abdominal findings encompassed pneumobilia which required immediate attention. In fact, most of the CT studies reported a minority of NCFs in the abdomen ranging from (1–38 %). Atalay et al. (2011) conducted his study on fewer number of patients (257), where (29 %) of NCFs and (19 %) of all significant non cardiac findings (SNCFs) were in the abdomen.

It should be taken into consideration that cardiac CT may be the first unintended step to diagnose a hidden malignancy. Our study recounted 14 incidental abdominal masses (2 of which were malignant), One incidental neck mass and finally two chest masses (one is mediastinal hemangioma and the other is nodal). This was followed by pathological assessment confirming the radiological diagnosis (as stated in the results section). Flor, N. et al. (Flor et al., 2013), reported that the prevalence of cancer for 10 different studies including 5082 patients was 0.7 %. out of 29 detected malignancies, 21 (72 %) were lung cancers; three were thyroid cancers; two, breast cancers; two, liver cancers; and one was mediastinal lymphoma.

Although few, some vascular findings necessitated further intervention and assessment. These included congenital porto-systemic shunt, thrombosed umblical vein and iliac artery aneurysm.

4.1. Limitations

The first limitation is the retrospective nature of the study. Some desired clinical data would have been available if the study had been prospective and we had methodically planned to search for particular anomalies. This also, hindered follow-up in some patients.

The second limitation is that data collection depended on a single reader. It is obvious that adding a second one would add more value to our observations. Despite this, we are confident in our diagnostic ability in congenital heart diseases.

Finally, there is a fine line of distinction between significant and nonsignificant. In addition, a direct link of an anatomical abnormality to a clinical implication is not always simple because the pathophysiological consequences can be complex.

4.2. Conclusions

Extra-cardiac findings are common in patients undergoing cardiac multidetector CT, with a percentage of unexpected SECF about 73 %. Adequate tailored evaluation of all structures in the scanned field of view should be performed by pediatric radiology and cardiac imaging expertise to ensure urgent interventions can be undertaken when necessary.

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Ethics approval and consent to participate

Written informed consent was waived by the Institutional Review Board (IRB), Institutional Review Board (IRB) was obtained, IRB approval: R.23.05.2180.

Conflicts of interest

The authors state that no conflict of interest was declared.

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