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ORIGINAL ARTICLE

Preoperative assessment of tetralogy of Fallot variants and associated anomalies by MDCT cardiac angiography

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ABSTRACT

Background: Tetralogy of Fallot (TOF) is the most common cyanotic cardiac disease in children and is responsible for 7 -10% of all congenital abnormalities.MDCT has a limited role in the primary diagnosis of TOF, however, it plays an important role in accurate delineation of the intracardiac and extracardiac anomalies thus helps the treatment planning and improves the surgical outcome. This study aims to highlight role of MDCT angiography in OF variants and associated anomalies.

Patients and methods: Thirty patients (17 males and 13 females) with an age range of 3–74 months underwent MDCT cardiac angiography using 128-detectors Philips Healthcare Ingenuity scanner and Dual source Canon medical system incorporation, aquilion prime sp. scanner.

Results: The most common variant of Fallot was tetralogy of Fallot (66.7%) followed by pentalogy of Fallot (30%), and triology of Fallot (3.3%).Other variants include :double out let right ventricle (DORV) type Fallot (30%), Fallot with endocardial cushion defect (6.6%), Fallot with pulmonary atresia (26.7 %), and Fallot with absent pulmonary valve syndrome (3.3%).Associated intracardiac anomalies represent (33.3%), Systemic arterial abnormalities represent (23.3), Systemic venous abnormalities represent (23.3), Coronary arteries anomalies represent (3.3%). Associated Pulmonary arterial anomalies were found among46.7 % of cases.

Conclusion:MDCT cardiac angiography is a strong and indispensable modality in preoperative evaluation of TOF patients as it can delineate associated intracardiac and extracardiac anomalies. It provides complementary data to echo cardiography regarding the pulmonary arteries, coronary arteries and tracheobronchial tree abnormalities.

Keywords: Multidetector computed tomography; tetralogy of Fallot; pulmonary artery anomalies, Fallot variants. absent pulmonary valve syndrome.

INTRODUCTION

Congenital heart disease (CHD) affects between 0.8 and 1.2 % of all live births around the world.The most prevalent cyanotic cardiac condition in children is Tetralogy of Fallot (TOF). It is responsible for 7% to 10% of all congenital abnormalities(1).TOF results from anterior deviation of the infundibular septum and is characterized by a tetrad of ventricular septal defect (VSD), aortic overriding, obstruction of the right ventricular outflow tract (RVOT), and right ventricular hypertrophy, However multiple variants and associations have been described (2).

The initial diagnostic modality of choice is echocardiography. It performs a thorough examination of the anatomy, calculates the pressure gradient across the RVOT, and determines the degree of RVOT obstruction.But it cannot detect the degree of pulmonary stenosis or associated extracardiac anomalies,additionally its spatial resolution is limited by its poor acoustic window (3). Complete delineation of the associated extracardiac anomalies in TOF is essential for treatment plan. The use of cardiac catheterization is now limited to cases with unclear pulmonary artery anatomy and to confirm the presence of an anomalous coronary artery, as it is invasive (can cause vessels damage, stroke, bleeding, and infection), has a long procedure time, may require sedation, and exposes patients to relatively high doses of ionizing radiation (4-5).

Due to its highspatial and temporal resolution and therapid image acquisition, MDCT is considered one of the most suited modality for the delineation of intra and extracardiac abnormalities.The images are processed in a variety of ways (multiplanar

reformation (MPR), maximum intensity projection (MIP), and volume rendering (VR), giving them a lot of flexibility in terms of visualization and surgical planning (6-8).the use of a prospective ECG gated technique significantly reduces the radiation dose to the child by limiting the exposure to a preselected window in a single cardiac cycle (7).

The aim of this study was to highlight the role of MDCT angiography in preoperative diagnosis of TOF variants and associated anomalies.

METHODS

Study design and population

This is an observational cohort study that was conducted at Radio-diagnosis department during 8 months. The Data were collected from 30 patients with TOF diagnosed clinically and by transthoracic echocardiography (TTE). They were 17males (56.7%) and 13 females (43.3%) with male predominance.Their ages ranged from 3 to 74 months with a mean age of (21.75 ± 30.04 months).The study protocol was approved by the institution's medical ethics committee, faculty of medicine and Parents' written informed consent was obtained. The study was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

The main clinical presentation was fatigability and low cardiac output symptoms. Patients with associated renal impairment, hypersensitivity to iodinated contrast agents and severely ill patients were excluded from the study.

Patient preparation

- Fasting for 4–6 hours.
- Sedation for Patients under the age of 74 months or who were uncooperative by an anesthesiologist.
- Cannulation: a large-bore peripheral IV cannula, at least a 22G was inserted at right antecubital vein or leg vein.
- Non- ionic contrast media injection (Iohexol 350 mg Iodine/ml)(weight-based at 2 mL/kg, with dilution of contrast material by normal saline at 1 mL/kg (2:1 contrast material to normal saline solution)) by an automated power injector (Medrad, Indianola, PA) at a rate of 1.0 ml/s for smaller children to 3.0 ml/s for larger children followed by saline injection

Scan protocol and parameters

All cases were scanned by either a128-detectors scanner (Philips Healthcare Ingenuity, Philips Medical System, Best, The Netherlands) or Dual source CT scanner (Canon medical system incorporation,aquilion prime sp, tsx-303b, Japan). The Scanning parameters were:Detector collimation of 64 x0.625 mm at 0.625-mm increments and with a gantry rotation time of 0.35 s, 150 mAs, 80 kVp.

Patient position

The patient laid supine, head first, the area from the thoracic inlet level to the L1–2 level was scanned in the caudocranial direction.

CT Scan Protocol

A large ROI was placed at the four cardiac chambers with trigger threshold of 150 HU. When the trigger threshold was achieved, the scan began immediately. A semi-prospective ECG triggering technique was used.

Post procedure care

-After the procedures, the patient is monitored for 15minutes to ensure good vital signs.

Image analysis:

Images were transferred to a dedicated workstation (Phillips workstation or vitrea workstation), and were interpreted by two radiologists with 8 and 15 years' experience in cardiac imaging using the source images and numerous image reformatting techniques, such as linear or curved planar reformatting, maximum intensity projection (MIP), minimum intensity projection (MIP), shaded surface display, and volume rendering (VR).

Images were interpreted for the following:

- **Cardiac observations:**Situs, concordance, septal defect, chambers size,Pericardial effusion, great vessel relationship.
- **Extra-cardiac observations**: Arteries (aorta, pulmonary arteries, coronary artery), Veins(pulmonary veins, systemic veins), extracardiac structures (lung fields, airways, pleura and upper abdomen)

Statistical Analysis

The data analysis was performed using SPSS 20 (ChicagoSPSS,SPSS Inc., Chicago, IL).Qualitative data were expressed as number and percent. Quantitativedata were displayed as mean and SD.

RESULTS

The most common clinical presentation of our patients was dyspnea,followed by low cardiac output manifestation,cyanosis, feeding problem and poor growth.

In our study, most cases (93.4 %, n:28)had situs solitus,levoposition, levocardia with atrioventricular and ventriculoarterial concordance(AV and VA concordance). 6.6% of cases had situs ambiguus: in the form of mixed heterotaxy with levocardia and AV discordance(mono-atrium) in one case and right atrial isomerism with dextroposition , dextrocardia, A-V and V-A concordance in the other case.

Three variants of Fallot were identified in our study (trilogy, tetralogy, and pentalogy). The most

common variant was tetralogy (66.6%; n:20) followed by pentalogy (30%; n:9)(figure1), then trilogy of Fallot in only (3.3%; n:1).Other variants include Fallot with pulmonary atresia (26.7 %) (figure 2),DORV type Fallot (30%)(figure 3), Fallot with endocardial cushion defect (6.6%)(figure3,4), and Fallot with absent pulmonary valve syndrome (3.3%).

The classic findings of TOF and its variants

In the current study the four classic findings of TOF were found in 100% of cases(table1).RVOT stenosis was either isolated subvalvular (26.7%), valvular(23.3%), supravalvular (3.3%) stenosis or mixed type involving more than one level in (46.7%) of cases. Regarding the overriding aorta, thirty percent of cases (n:9)had DORV type Fallot where >50% ofthe aorta aligned with the right ventricle. 22% of DORV cases had additional ASD and were diagnosed as Pentalogy of Fallot.Perimembranous outlet VSD was found in 73.3% of cases, Muscular outlet VSD in 23.3% while atrioventricular septal defect (AVSD) represented 6.6% of cases.The mean diameter of VSDs was 12.65± 6.1mm.

The associated congenital anomalies

Eighty associated congenital anomalies were detected among 90% of cases(table2).

- **The associated intracardiac anomalies:**

The intra-cardiac anomalies were detected in 33.3% of the cases in the form of: atrial septal defect(ASD) in29.9% of cases(secundum ASD in13.4 %", patent foramen ovale (PFO) in 6.6 %, primum ASD in 6.6 % and superior sinus venosus ASD in 3.3 %), Atrioventricular septal defect was noted in 6.6% of cases.

- **The vascular extracardiac anomalies:**

Sixty-sixVascular extra-cardiac anomalies were detected among 86.6% of cases; 36.6% of the cases had systemic arterial abnormalities,Aortic root dilation/aneurysm, ductus diverticulum, and bovine aortic arch were the most common accounting for 13.3% each. Systemic venous abnormalities were found in 23.3% of cases where the persistent left intercostal vein was the most common by 10% of all cases .3.3% of cases have coronary arteries anomalies .20% of cases have pulmonary venous anomalies.

- **The extra-cardiac non vascular abnormalities:**

13.3 % of cases had extra-cardiac non vascular abnormalities in the form of right tracheal bronchus or hepatic cyst.

The associated pulmonary arterial anomalies

In our study 50% of cases had associated pulmonary arterial anomalies(table3).MPA was normal in 60% of cases, the most common anomalies in MPA was atresia in 13% of all cases. The RPA was normal in 73.3 % of cases,the most common anomalies in RPA was hypoplasia in 13.3 % of all cases. The LPA was normal in 76.6 % of cases,the most common anomalies in LPA was hypoplasia and focal stenosis by (13% each of all cases).Only one case (3.3) has total pulmonary atresia. 10% of cases showed dilated pulmonary arteries secondary to absent pulmonary valve syndrome (n:1), patent ductus arteriosus (n:1) and supravalvular pulmonary artery membrane (n:1).Theaorto-pulmonary connections were found among 66% of cases in the form of PDA (60% of cases) or MAPCAs(20% of cases).

The McGoon ratio was calculated for all cases, the mean value was 2.44±1.23 and 30% of cases were below the cutoff value (1.7).

Table (1): The classic findings of Fallot and their variants

Findings	No.	%
RVOTO		
Isolated subvalvular stenosis	8	26.6
Isolated valvular stenosis	7	23.3
Isolated supravalvular stenosis	1	3.3
Subvalvular and valvular stenosis	8	26.6
Valvular and supravalvular stenosis	5	16.6
Mixed subvalvular ,valvular and supravalvular stenosis	1	3.3
Aortic overriding		
<50% from RV	21	70
>50% from RV (DORV type)	9	30
VSD		
Perimembranous outlet VSD	22	70
Muscular outlet VSD	7	23.3

Findings	No.	%
Atrioventricularseptal defect (AVSD)	2	6.7
RV dilatation/hypertrophy	**30**	**100**

RVOTO:RT ventricular outfkow tract obstruction ,RV:right ventricle ,DORV: double outlet right ventricle ,VSD :ventricular septal defect ,AVSD: Atrioventricular septal defect

Table(2): Associated anomalies and variants

Associated anomalies	Patient No.	%
Total Anomalies	**27**	**90**
I.Intracardiac anomalies	**10**	**33.3**
ASD	9	29.9
AVSD	2	6.6
II.Vascular extra-cardiac abnormalities	**26**	**86.6**
(A) Systemic arterial abnormalities	**11**	**36.6**
Bovine aortic arch	4	13.3
Aberrant RT SCA	2	6.6
Aberrant LT SCA	1	3.3
RT sided aortic arch	1	3.3
Aortic root dilation/aneurysm	4	13.3
Ductus diverticulum	4	13.3
(B) Systemic venous abnormalities	**7**	**23.3**
Persistent left superior intercostal vein	3	10
Persistent LT SVC	2	6.6
Aberrant LT BCV (retroaortic BCV)	1	3.3
IVC interruption with hemiazygous continuation	1	3.3
(C) Coronary arteries anomalies	**1**	**3.3**
(D) Pulmonary venous abnormalities	**6**	**20**
Conjugated LT pulmonary veins	3	10
Conjugated RT pulmonary veins	2	6.6
left pulmonary venous varix	2	6.6
(E) Pulmonary arteries anomalies	**14**	**46.7**
(F) Aortopulmonary connection	**20**	**66.6**
III.Non vascular extra-cardiac abnormalities	**4**	**13.3**
RT tracheal bronchus	3	10
Hepatic cystic lesions	1	3.3

(ASD :atrial septal defect ,AVSD :atrioventricular septal defect ,RT: right ,LT :left ,SCA: subclavian artery ,SVC :superior vena cava ,IVC :inferior vena cava ,BCV: brachiocephalic vein)

Table (3): Distribution of associated pulmonary arteries anomalies

pulmonary arterial anomalies	Atresia Patient % (n)	Hypoplasia Patient % (n)	Focal stenosis Patient % (n)	Dilated Patient % (n)
Total pulmonary atresia	3.3 (1)	-	-	-
MPA	13.3 (4)	20 (6)	6.6 (2)	3.3 (1)
RPA	6.6 (2)	13.3 (4)	6.6 (2)	3.3 (1)
LPA	3.3 (1)	10 (3)	10 (3)	3.3 (1)
Absent pulmonary valve syndrome	-	-	-	3.3 (1)
Total	26.7 (8)	43.3 (13)	23.3 (7)	10 (3)

(MPA: main pulmonary artery ,RPA :right pulmonary artery ,LPA :left pulmonary artery)

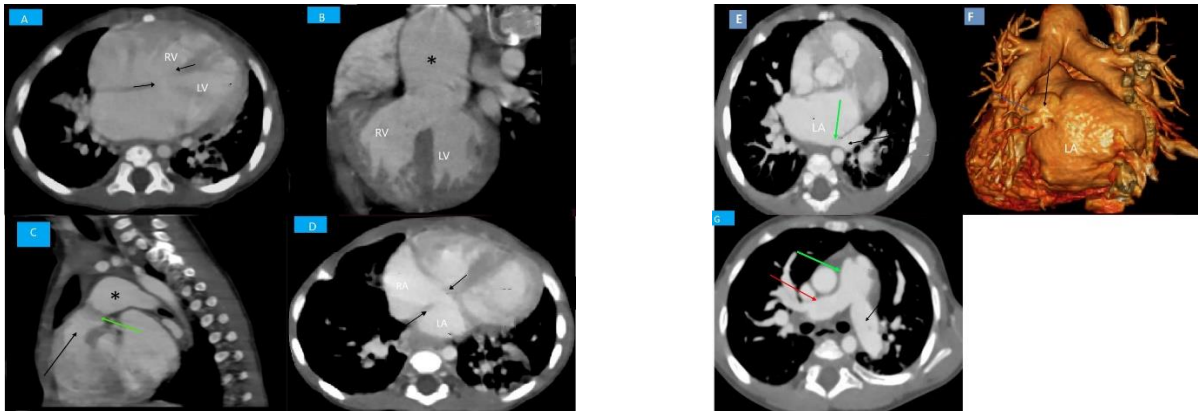

Figure 1: Pentalogy of Fallot with absent pulmonary valve syndrome and Lt pulmonary vein osteal stenosis.9 -month -old boy presented with dyspnea and cyanosis .MSCT reveals: (a) axial MIP image shows subaortic outlet VSD (black arrows) measuring 11.5 mm. (b) oblique MIP image shows overriding aorta (asterisk) (45% from RT ventricle & 55% from LT ventricle).(c) ObliqueMIP imageshows dysplastic thickened pulmonary valve (green arrow) and thick anteriorly displaced cristasupra-ventricularis exerting subvalvular and valvular RVOT stenosis(black arrow) with post stenotic MPA (asterisk) dilatation.(d) axial MIP image shows premium ASD (black arrows) measuring about 5 mm, incidental extra cardiac pulmonary finding noted depicted as left lower lobe consolidation. (e,f) axial MIP and VR images shows dilated left atrium with conjugated (black arrow) leftsuperior pulmonary veins (blue arrow) and left inferior pulmonary vein (red arrow) with osteal stenosis (2.5mm).(g)axial MIP image of MPA(green arrow) measuring 16 mm ,RPA(red arrow) measuring about 9.1mm ,LPA (black arrow) measuring about 10.5 mm

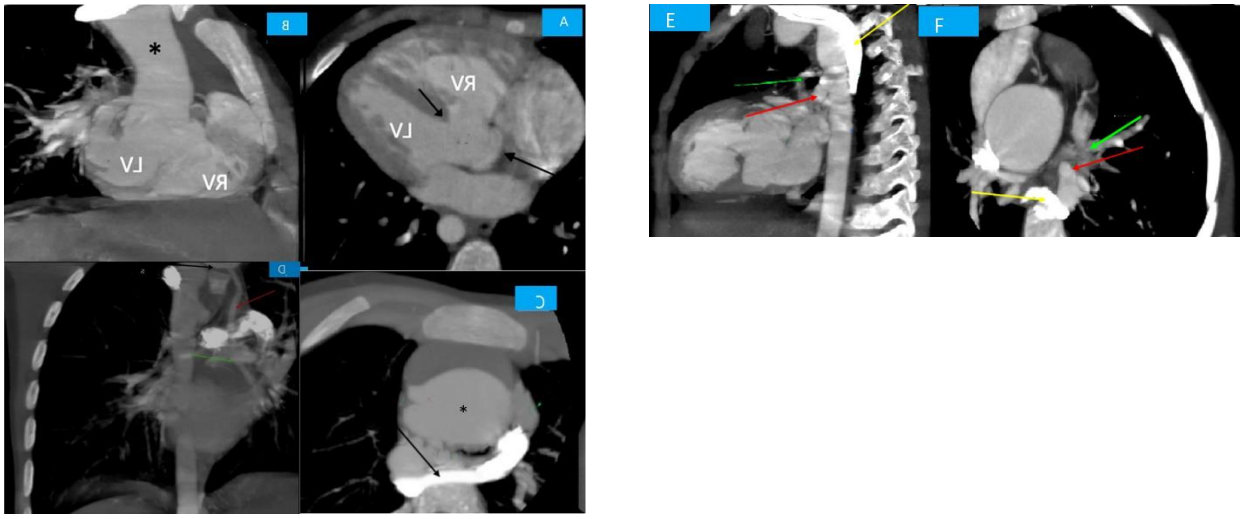

Figure 2: TOF with total pulmonary atresia,ascending aortic aneurysm,MAPCAs and aberrant left BCV.3 -year -old girl presented with dyspnea and easy fatigability.(a) axial MIP image shows subaortic outlet VSD (black arrows)(19mm).(b) Oblique MIP images shows Overriding aorta (asterisk) (45% from RT ventricle & 55% from LT ventricle). (c) axial MIP images at level of main pulmonary artery shows absent MPA and its main branches with ascending aortic aneurysm (35mm) (asterisk) and aberrant LT BCV (black arrow) with retro aortic prevertebral course posterior to the trachea (d) oblique MIP image of a MAPCA (red arrow)(4mm) from subclavian artery (black arrow) to RT lung hilum (green arrow).(e ,g ,h) coronal ,sagittal and axial MIP image of MAPCA(red arrow)(5mm) arising from descending aorta to LT lung hilum (green arrow) with aberrant LT BCV (yellow arrow).

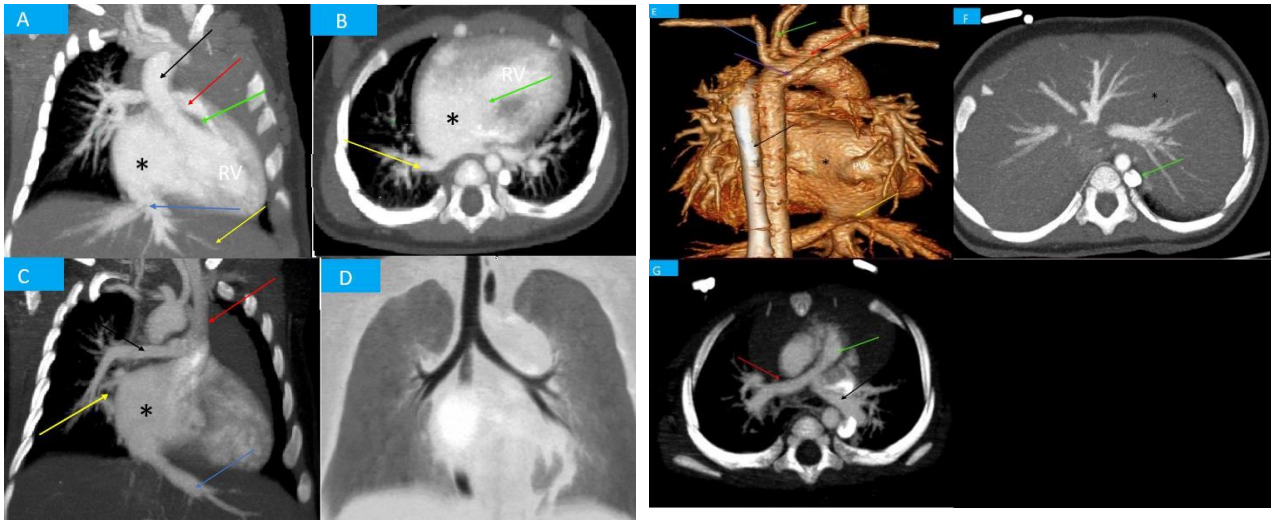

Figure 3:DORV type TOF with mixed heterotaxy, pulmonary artery hypoplasia,endocardial cushion defect and ARSCA. 8 months old girl presented with low cardiac output symptoms.(a): oblique MIP image shows a hypertrophied double outlet right ventricle (DORV) that gives rise to both aorta(black arrow) and MPA (red arrow) , infundibular hypertrophy (green arrow) exerting subvalvular RVOT stenosis ,midline transverse liver (yellow arrow) and interrupted IVC with confluent hepatic veins (blue arrow) draining directly at the dilated monoatrium (asterisk).(b,c) axial and coronal oblique images shows enlarged monoatrium (asterisk) that draining the pulmonary veins (yellow arrow) ,left sided SVC (red arrow) and confluent hepatic veins (blue arrow) with common atrioventricular canal defect (green arrow) and hypoplastic RPA (black arrow) (4.7 mm).(d) coronal MinIP image shows left bronchial isomerism with focal stenosis of the distal left main bronchus secondary to ARSCA.(e) 3D-VR image (posterior view) reveals right sided monoatrium (asterisk) that draining the pulmonary veins and hepatic veins (yellow arrow)with interrupted IVC and hemizygous continuation (black arrow).Abnormal branching pattern of aortic arch (common carotid trunk (red arrow), left vertebral artery (green arrow) ,LSCA (blue arrow) ,ARSCA (purple arrow)).(f)Axial MIP image shows: midline transverse liver (asterisk) with absent spleen ,absent IVC below hepatic veins level ,continued hypertrophied hemi azygous (green arrow).(g)Axial MIP image of MPA(green arrow),RPA(red arrow) and LPA(black arrow).

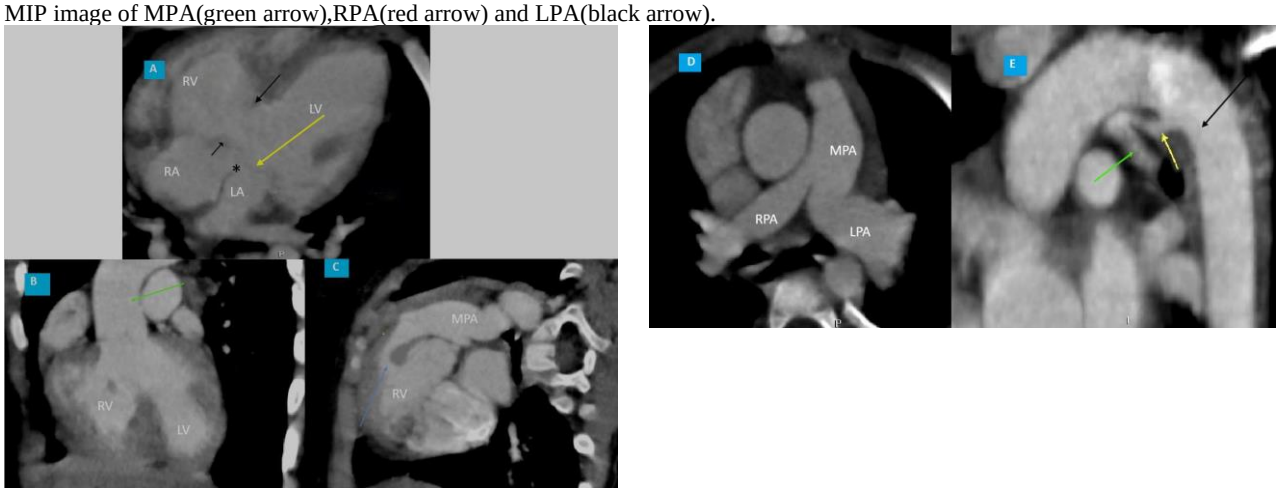

Figure 4: TOF with incomplete endocardial cushion defect. 2 -year -old girl presented with dyspnea and easy fatigability.(a) Axial MIP image reveals hypertrophied RV and AVSD: Common AV (yellow arrow) valve overrides both ventricles, Primum ASD (asterisk),Inlet VSD (black arrows) .(b)Oblique MIP image shows overriding aorta (green arrow) (45% from RT ventricle & 55% from LT ventricle).(c)Oblique MIP image shows RVOT stenosis (blue arrow).(d)Axial MIP images showing dilated LPA(e) Oblique MIP image showing s-shaped PDA(yellow arrow) connectingthe aortic arch (black arrow) to the dilated LPA (green arrow)

DISCUSSION

Tetralogy of Fallot (TOF) is one of the most prevalent congenital heart disease (CHD) (9). The advances in surgical techniques, anesthetic, and preoperative care as well as The preoperative accurate delineation of the intracardiac and extracardiac anomalies have substantially enhanced the surgical success rates and the life expectancy (8).

Although MDCT has a restricted role in the initial diagnosis of TOF, it is essential to evaluate the anomaliesof the pulmonary arteries, anatomical variants of TOF, the degree of aortic override, the presence of major aorto-pulmonary collaterals (MAPCAs). Moreover, itcan detect the anomalous prepulmonic course of the coronary arteries that are vulnerable to injury during the ventriculotomy incision required for TOF repair, thuspreclude a transannular / infundibular patch (9-12).

In our study 93.3 % of cases showed situs solitus with levocardia and AV concordance while 6.7% had situs ambigus . In (Moustafa et al ,2021)(13) 2.5% of cases showed situs ambiguous.

In our study, the most common type of Fallot presented was the tetralogy (66.6%) followed by pentalogy (30%) then the trilogy (3.3%),this agrees with (Moustafa et al ,2021)(13) who reported tetralogy of fallot in was 64 % and pentalogy was 36 % of cases. but differs from (El shimy et al ,2021)(14) who in which the tetralogy was (80%) and pentalogy was (20%).

In our study, 60% of cases had subvalvular (infundibular) pulmonary stenosis, 60% had valvular stenosis, 23.3% had supravalvular stenosis. (El shimy et al ,2021)(14) reportedsubvalvular stenosis in (23.3%),valvular stenosis in (70%), and supravalvular stenosis in (6.7%).(A. Hrusca et al 2016)(15) reported that (68.57%) of patients have infundibular stenosis, (17.5%) have valvular stenosis, (21%) with anomalous pulmonary arteries.In the study of (Moustafa et al ,2021)(13) Combined subvalvular, valvular, and supravalvular pulmonary stenosis was the most common type of RVOTO in (46.7%), followed by combined subvalvularand valvular level in 41.5%. While 3.8% showed isolated subvalvular, 2.59% had isolated valvular, and 2.59% had isolated supravalvular obstruction.

In the present study, the associated pulmonary arterial anomalies were noted among46.7%of cases. The commonest was pulmonary artery hypoplasia (43.3%) followed by pulmonary artery atresia (26.7%). complete pulmonary atresia was found in 3.3% of cases. Absent pulmonary valve syndromewith dilated pulmonary artery and its main branches (3.3%). The main pulmonary artery was atretic in 13.3% of cases,hypoplastic in 20%stenotic in 6.6%and normal 60 %.The right pulmonary artery was atretic in 6.6%, hypoplastic in 13.3%,stenotic in 6.6% and normal in 73.3%.The left pulmonary artery was atretic in 3.3% of cases, hypoplastic in 10% of cases,stenotic in 10% of cases and normal in 76.6% of cases.

In (El shimy et al ,2021)(14), Pulmonary artery defects were reported in 80% of cases: main pulmonary artery atresia (30%), hypoplastic main pulmonary artery (13.3%), atretic right pulmonary artery (16.7%) of cases and atretic left pulmonary artery in (20%) of cases.(Moustafa et al ,2021)(13) reported complete atresia in 2.6 % of cases .MPA was absent in 5.1%,hypoplastic in 29.8 % and stenotic in 5.1 %. RPA was absent in 3.9%,hypoplastic in 23.4% and stenotic in 3.9 % of cases.LPA was absent in 2.6 %,hypoplastic in 25.9 % and stenotic in 10.4 % of cases. (Tiwari A et al ,2020) (16) found that pulmonary artery abnormalities were found in 35 % cases.

The aortic overriding was classified according to the degree of aortic origin from right ventricle (RV/LV ratio), In 30% of cases the ratio was > 50%(Double outflow right ventricle) and was diagnosed as DORV type of Fallot.Zakaria et al ,2011 (17) and Moustafa et al, 2021 (13) reported DORV type of Fallot in 9 % and 19.5% of cases respectively.

In the current study, the incidence of atrial septal defect was 29.9 %. They were diagnosed with pentalogy of Fallot. El shimy et al ,2021 (14), Zakaria et al ,2011 (17), and Moustafa et al, 2021 (13) reported ASD in 20%, 4.3%, and 36.4% of case respectively.

In the present study, we found atrioventricular septal defect (AVSD) in 6.6 %of cases and was considered as a separate variant of Fallot and diagnosed as Fallot with associated endocardial cushion defect.

In our study we found aorto-pulmonary connection in 66.6 % of cases in the form of patent ductus arteriosis (PDA) in 60 % of cases or major aortopulmonary collaterals (MAPCAs) in 20 % of cases.Ductus diverticulum was noted in 13.3 % of cases.

El shimy et al ,2021 (14) reported a 45%incidence of aorto-pulmonary connections(PDA in 23.3% and MAPCSin 23.3% of patients). Zakaria et al ,2011 (17) reported that 57% of cases had aortopulmonary collateralcirculation.Tiwari et al ,2020 (16) found aortopulmonary collaterals in 37% and Patent ductus arteriosus in 29% of cases. In Moustafa et al, 2021(13)study aortopulmonary collaterals was detected in 74% of cases in which MAPCAs were seen at 28.5% , minor collaterals at 45.5%of cases and PDA in 35 % of cases

In our study,33.3% of case hadsystemic arterial abnormalities. 13.3% had bovine arch (a common brachio-bicephalic trunk) ,13.3 had ascending aortic dilatation/aneurysm as a complication, 3.3% hadright sided arch ,3.3% had an aberrant right subclavian artery (ARSCA) and 3.3% had an aberrant left subclavian artery (ALSCA).In (El shimy et al ,2021) (14) study ,26.7 % had right-sided aortic arch and 3.3% had ALSCA. In (Zakaria et al ,2011) (17) study, 9% of cases had associated ascendingaortic dilatation, 22% of cases showed a common brachio-cephalic trunk, 4% was associated with ALSCA.(Tiwari et al ,2020)(16) found that 19 % of cases have right sided aortic arch, and 3% of patients had bovine arch.In (Moustafa et al, 2021) (13) a bovine arch was detected in 22.8% of cases.

In the present study, the incidence of systemic venous anomalies was 23.3% as follows: 10% of cases had persistent left superior intercostal vein,6.6 % of patients had persistent left SVC (PLSVC),3.3 % of cases showed an aberrant left brachiocephalic vein with retroaortic course and

3.3% had IVC interruption with hemiazygous continuation. Moustafa et al, 2021(13) found that 3.8% of cases had retro aortic brachiocephalic vein and PLSVC was found in 10.3% of cases. El shimy et al ,2021(14) reported aberrant left brachiocephalic vein in 4.4 % of cases.

In our study we found that 20 % of cases had pulmonary venous abnormalities:10 % of cases showed conjugatedleft pulmonary veins,6.6 % hadconjugatedright pulmonary veins and 6.6 % of cases hadleft pulmonary venous varix.

We detected coronary artery anomalies in 3.3 % of cases. Also Sheikh et al ,2014(19) detected coronary artery anomalies in 4.9 % of cases while a higher incidence was reported by El shimy et al ,2021(14) and Hrusca et al ,2016 (15) (20 % and 22.85%respectively).

The McGoon ratio was calculated by dividing the sum of the left and right pulmonary arterial diameters by the diaphragm aorta diameter. The McGoon ratio was below the cutoff value of 1.7 in nine cases (30 %), while the rest of the cases yielded normal values with mean value 2.44±1.23.That was the same reported by Zakaria et al ,2011 (17) . Moustafa et al, 2021(13) reported a lower value of the McGoon ratio (mean; 1.8 ± 0.81).

An excellent interobserver agreement(kappa measure of agreement 0.76)was found regarding the diagnosis of the Fallot variants as well as all associated congenital anomalies and variants. We recommend performing MDCT cardiac angiography as a routine tool for preoperative evaluation of TOF patients. It provides complementary data to echocardiography with regard to pulmonary,coronary artery and tracheobronchial tree anatomy and can non-invasively delineate associated cardiac and extracardiac anomalies.

The main limitation of this was the cases with sever cardiopulmonary dysfunction who were unfit for sedation

CONCLUSION

MDCT cardiac angiography is a strong and indispensable modality in preoperative evaluation of TOF patients as it can delineate associated intracardiac and extracardiac anomalies. It provides complementary data to echocardiography regarding the pulmonary arteries, coronary arteries and tracheobronchial tree abnormalities.

List of abbreviations

TOF: tetralogy of Fallot , CT: Computed tomography, MRI: magnetic resonance imaging, CMR : cardiac magnetic resonance , MPR: multiplanar reformatted, MinIP: minimum intensity projection, IRB (Institutional review board), , MDCT: multi detector computed tomography, VR: volume rendering, CHD: congenital heart disease ,VSD: ventricular septal defect , RVOT : Right ventricular outflow tract ,RVOTO : Right ventricular outflow tract obstruction , IV : intravenous , ECG : electrocardiography, GFR : glomerular filtration rate , ROI : region of interest , KV: kilovolt ,Mas : milliampere second , AV : atrio-ventricular ,VA : ventriculoarterial ,DORV : double outlet RT ventricle , MPA : main pulmonary artery , RPA : RT pulmonary artery , LPA : LT pulmonary artery , MAPCA: major aortopulmonary collaterals ,RA : RT atrium , RV : RT ventricle , LA : LT atrium , LV : LT ventricle , AVSD : atrioventricular septal defect , ASD : atrial septal defect , PFO : patent foramen ovale , PDA : patent ductus arteriosus ,BCV : brachiocephalic vein , LSVC : LT superior vena cava .

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