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Cardiac MRI to evaluate right ventricular function after surgical correction of congenital heart diseases

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***Abstract*---**Background: Cardiac MRI (CMR) is a noninvasive imaging technique that plays an important role during clinical follow-up of postoperative CHD patients. MRI can provide valuable information on cardiac anatomy, ventricular function, valvular function, and on the presence and location of myocardial scar tissue. Our study aimed to assess the right ventricular function after surgery in patients with congenital heart diseases & assessment of myocardial viability with particular attention to scar tissue in the ventricular myocardium aside from sites of previous surgery (e.g., ventricular septal defect and right ventricular outflow tract patches). Results: The most common encountered CHD in this study were tetralogy of Fallot &transposition of great arteries. The most common postoperative complication detected by CMR was pulmonary regurgitation particularly in repaired TOF patients. Regarding the RV volume & function, there was statically significant increase in RVEDVI &ESVI in patients with decreased RVEF with good correlation with echocardiographic results.

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Patients post TGA arterial switch repair showed less complications than atrial switch repair with better RV postoperative function. Most patients showed no residual shunting (QP/QS =1). Conclusion: CMR is able to effectively identify post-procedural anatomical and functional intra- and extracardiac information, thus allowing accurate diagnosis of postoperative complications in most patients.

***Keywords*---**cardiac magnetic resonance, congenital heart diseases, myocardium, ventricular function.

Introduction

The right ventricle is of great important role in patients with congenital heart diseases (CHD) as it may support the pulmonary or systemic circulation. The RV function in repaired congenital heart diseases patients is essential to be accurately evaluated for early management and intervention of complicated postoperative CHD patients for better outcomes & prognosis (1) . The need for diagnosis of RV dysfunction is evident. In patients with repaired congenital heart diseases, a better understanding of the impact of surgical valve replacement on ventricular mechanics may lead to improved indications and outcomes. Therefore, cardiovascular magnetic resonance (CMR) feature tracking analysis is used to quantify ventricular strain and synchrony in repaired cardiac patients (2).

Due to the complex geometry of RV, large volume & disturbed anatomy in postoperative CHD patients, volume measurements and functional assessment by echocardiography wasn't accurate enough and RVEF was accurately & better assessed by cardiac MRI which is now considered the as the reference standard for evaluation of RV function particularly in post-operative patients (3) . Cardiac MRI (CMR) is a noninvasive imaging technique that plays an important role during clinical follow-up of postoperative CHD patients. CMR is not hampered by geometrical assumptions or by the acoustic window, which may limit echocardiographic imaging in postoperative CHD patients as a result of abnormal cardiac anatomy or scar tissue. Moreover, as no ionizing radiation is needed, the application of CMR is safe and can be used for repeated evaluation of CHD patients during long-term follow-up. CMR provides various acquisition schemes such as black- blood spin echo (BBSE), bright-blood gradient echo (GRE) imaging, phase-encoded flow imaging, three- dimensional contrast-enhanced angiography (3D- MRA) and late gadolinium-enhanced imaging (4).

CMR is superior, more accurate & preferred than echocardiography due to its capability to identify intracardiac anatomical, functional, ventricular volume measurement especially in cases with large RV volumes & structural abnormalities, tissue characterization and postoperative complications following congenital heart diseases surgical procedures (5).

Objectives

One of the most important prognostic features that can be detected & identified by CMR is myocardial fibrosis which is characterized by areas of late enhancement in gadolinium enhanced images, it has been shown that the presence and extent of late enhancement is predictive of arrhythmia and sudden death particularly in repaired TOF patients (6) .

The limitations of CMR are few such as higher cost in comparison with echocardiography, lack of portability, limited availability, artifacts from implants containing stainless steel and relative contraindication in patients with pacemaker or defibrillator. Hence, on balance, the clinical benefits of the data obtained by CMR greatly outweigh its limitations (7).

Methods

Aim: To assess the right ventricular function after surgery in patients with congenital heart diseases & assessment of myocardial viability with particular attention to scar tissue in the ventricular myocardium aside from sites of previous surgery (e.g., ventricular septal defect and right ventricular outflow tract patches).
Study design: Prospective study.
Study Setting: Radiodiagnosis department, faculty of medicine, Tanta university hospitals, Tanta, Egypt.

Inclusion criteria

- ✓ Known cases of congenital heart diseases underwent surgical procedures.
- ✓ Hemodynamically stable patients

Exclusion criteria

- ➢ Hemodynamic instability or acute respiratory insufficiency.
- ➢ Altered mental status.
- ➢ Advanced decompensated congestive heart failure.
- ➢ Patients who are contraindicated to perform MRI.
  a) Patients with intraocular metallic foreign body (e.g., metal shavings).
  b) Patients with non CMR compatible cardiac pace makers.
  c) Patients with MR non compatible intracranial clips of arterial brain aneurysms.
  d) Neural stimulator (e.g., TENS -Unit).
  e) Any type of ear implant.
  f) Any implanted device (e.g., insulin pump, drug infusion device).
  g) Metal shrapnel or bullet.
  h) Patient who refuse the examination.
  i) Patient with renal impairment.
  j) Claustrophobic patients.

The study was conducted on 40 patients post operated for congenital heart diseases. All patients in the study were subjected to informed consent, good history &clinical examination, ECG, plain chest X-ray, 2D transthoracic echocardiographic assessment. Cardiac magnetic resonance imaging with IV contrast examination was conducted on all patients for evaluation of function &volume of RV and detection of any postoperative complications. The standard CMR protocol included T2-weighted black-blood shortinversion time turbo spin-echo imaging (T2WI), cine balanced steady-state free-precession sequences (cine SSFP) and T1-weighted contrast-enhanced inversion recovery segmented gradient echo sequence (LGE-T1WI) acquired 10–15 min after the intravenous administration of 0.2 mmol/kg gadolinium for the evaluation of the late gadolinium enhancement (LGE).

Morphological T1-weighted FSE black blood sequences were added to the above protocol only for specific indications (e.g., morphology assessment and tissue characterization in suspected arrhythmogenic right ventricular cardiomyopathy [ARVC]) combination of imaging in different cardiac planes were used for better depict cardiac structures and therefore all sequences were performed on short axis, four-chamber and RV inflow-outflow views. The ventricular volume was calculated by multiplying the blood pool area on all slices on which the ventricle is visible with the slice thickness .to calculate the blood pool volume, the endocardial contour was drawn on each slice covering the ventricle.

Then both ejection fraction and cardiac output were calculated by using the following formula:

- Ejection Fraction (%) =Stroke volume (ml)/ED volume (ml)
- Cardiac output (ml/min) = Stroke volume (ml)x Heart rate (bpm)

2D phase contrast flow: ECG triggered 2D phase contrast sequences were acquired for flow measurements and quantification of pulmonary regurgitation. The imaging plane was set perpendicular to flow in the main pulmonary artery as well as right and left pulmonary branches.

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The KolmogorovSmirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation, median and interquartile range (IQR). Significance of the obtained results was judged at the 5% level.

Results

- The study population was divided into two groups. Group I included 26 patients with normal RVEF (CMR RVEF > 50%) and the other group included 14 patients with fair or reduced RVEF (CMRRVEF<50%). The age of the patients ranged from 5 months to 42 years old with a mean age of 13 years old ± 11.2 SD, with statistically significant difference between both groups (p =0.023). The body surface area of patients ranged from 0.34 – 2.3 m2 in group I with a mean of 1.2 0.6 m2 and ranged from 0.2 -1.9 m2 in group II with a mean of 1.1 m2. There was no statically significant difference between both groups (P=0.645).
- Abnormalities in chest X-ray (including RV enlargement, right atrial enlargement & prominent pulmonary knuckle), 30 patients (75%) had x ray abnormalities, 17 patients in group II (65.4 %) & 13 in group I (92.9%). The other 10 patients showed no significant x ray abnormalities, with

statistically significant difference between the studied groups (P =0.039) (Fig 1).

- ECG abnormalities including right ventricular strain, right atrial enlargement, atrial fibrillation, atrial tachycardia, premature ventricular contractions & right bundle branch block), 16 patients had ECG abnormalities, 13 in group I (50 %), 3 in group II (21.4 %), with significant difference in the studied groups (P = 0.049).
- Considering the Echo diagnosis**:** 21 patients (52.5%) had tetralogy of Fallot (TOF), 4 patients in group I & 17 patients in group II, 11 patients (27.5 %) with transposition of great arteries (TGA), 4 in group I & 7 in group II, Other congenital heart diseases were included: as double outlet right ventricle (DORV), single ventricle, partial anomalous pulmonary venous return as scimitar syndrome (PAPVR), ASD& VSD: 8 patients (20%), 6 patient in group I & 2 in group II, with statistically significant difference between the two groups concerning the TOF diagnosis (P=0.05) (Fig 2).
- 18 TOF patients underwent total repair by either transannular patch (5 patients 27.7%), RVOT patch (3 patients 16.6%) & RV-PA conduit (10 patients 55.5 %). 11 TGA patients underwent atrial switch repair either by mustard (3 patients 27.27 %) or senning (2 patients 18.1%) & arterial switch repair (6 patients 54.5 %). Other 11 patients underwent MBT shunt as primary repair of TOF patients (3 patients 27.2 %), PA banding for PH in DORV patients (2 patients 18%), Fontan (3 patients 27.2%) and Glenn (3 patients 27.2 %) procedures for single ventricle, cc TGA & DORV repair (Table 1).

CMR RV Volumes

The RV end diastolic volume index (RVEDVI)

End diastolic volume index in group I was 166.5 ± 51.16 ml / m2 & in group II was 104.962 ±52.01 ml / m2, with a statistically significant difference between the studied groups (P =0.001) with negative correlation between RVEDVI &RVEF (r= -0.621) **.**

The RV end systolic volume index (RVESVI)

End systolic volume index in group I was 98.42 ± 34.3 ml / m2 & in group II was 48.54 ± 26.63 ml / m2, with a statistically significant difference between the studied groups (P < 0.001) with negative correlation between RVESVI &RVEF (r= -0.758) (Fig 3).

The RV stroke volume index (RVSVI)

Stroke volume index in group I was 69.07 ± 20.61 ml / m2 & in group II was 59.59 ± 29.41 ml / m2, with no statistically significant difference between the studied groups (P value =0.292).

The relation between the method of surgical repair of TOF patients & RV volume and function

The highest CMR RVEF was measured in patients underwent TOF repair with RVOT patch (mean 56.21± 10.07%) then RV-PA conduit (mean 50.8 ±9.05 %) and lastly transannular patch with the least RVEF (mean 48.7 ±7.5 %). There was no statically significant difference between the three groups ($p = 0.47$). RV EDVI & ESVI were higher in patients repaired with transannular patch in comparison to the other two operations (means 164.5 ±50.12 ml /m2 & 95.41±32.65 respectively in transannular patch), while in RVOT & RV-PA conduit repair measurements were (means 102±35.64 & 45.23±24.33, 92.56 ±26.12 & 40.36±18.05 ml /m2 respectively). There was statically significant difference between the three groups according to RVEDVI& ESVI (p =0.003, 0.04) respectively (Table 2).

The relation between the method of surgical repair of TGA patients & RV volume and function

RVEF measured by CMR was higher in patients with TGA underwent arterial switch repair than patients post atrial switch repair with means 52.13 ± 9.82% & 45.63 ± 4.56% respectively with no significant difference between both groups. RVEDVI & ESVI were larger in post atrial switch patients in comparison to post arterial switch patients, means in post atrial switch was 165.32 ±56.24 ml/m2 & 90.78± 31.30 ml/m2 respectively, while in post arterial switch means was 99.34±50.20 & 42.60±16.82 ml/m2 respectively. There was statically significant difference between both groups regarding RVEDVI& ESVI (P = 0.01 &0.04 respectively)(Table 3).

Post-operative complications by CMR

Totally repaired TOF patients (18), showed by CMR pulmonary branch stenosis in 7 patients (38.9), patch dilatation (6 patients 33 %), PR (6 patients 33 %) showed as black jet of blood appear in cine image after closure of the pulmonary valve, RVF with low RVEF <40% (1 patient 6%), RVD &TR (6 patients 33 %). Post TGA repair (11), developed TR (4 patients 36 %), RVF patient, baffle leak, baffle stenosis in post atrial switch (1 patients 9 % for each). Neo pulmonary obstruction & branch PA stenosis (1 patient 9 % for each) in post arterial switch. Patients post atrial switch (4 patients out of 5) developed more complications than those underwent arterial switch (only 2 patients out of 6). Other patients (11) showed MBT shunt stenosis, venous collaterals, branch PA stenosis, RAD, RVD &RVF (1 patient 9 % for each) (Table 4).

Right ventricular dilatation

The volume & function of RV was assessed by CMR in each patient, most patients showed volume overload, 30 patients (75%) had right ventricular hypertrophy / dilatation (17 patients were in group II (65.4 %), 13 patients were in group I (92.2 %), only 3 of them had RV failure (RVEDV >160 ml /m2). The remaining 10 patients showed no abnormalities in RV size & volume, with statistically significant difference between the studied groups regarding the RV dilatation (P =0.039).

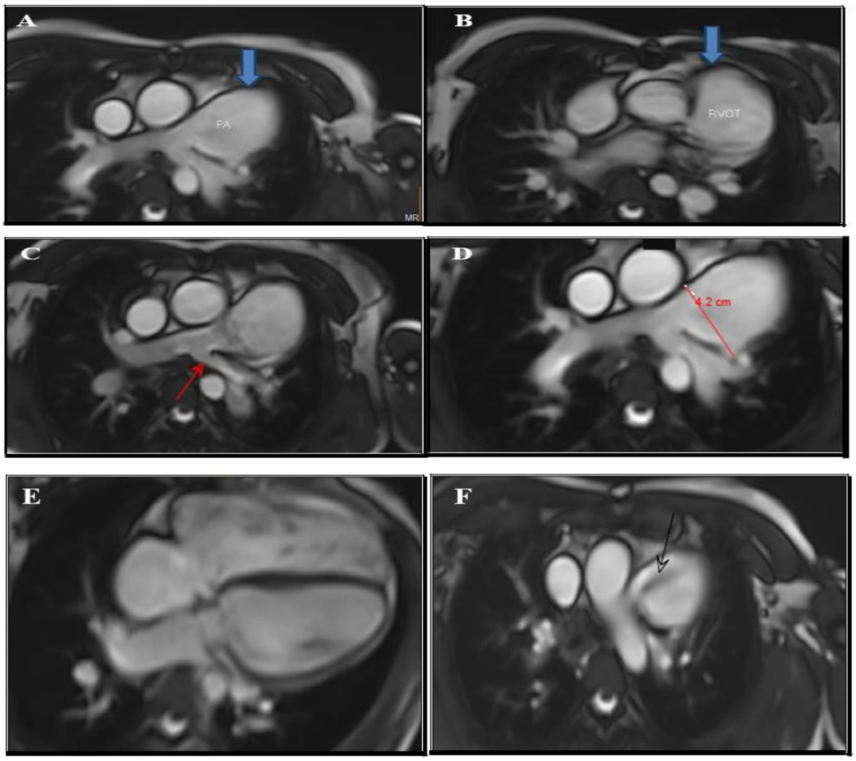
The pulmonary regurgitation fraction (RF):

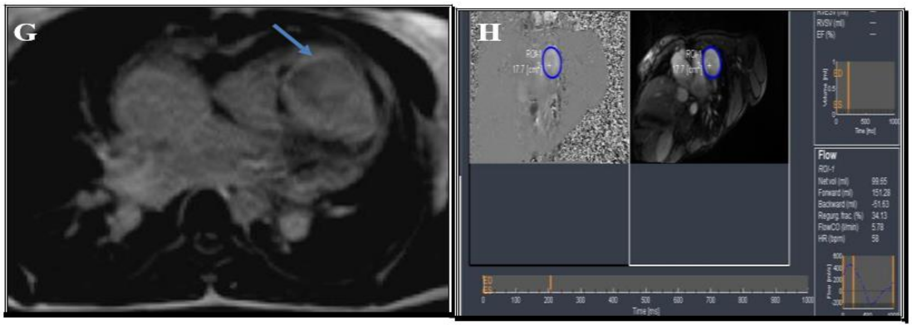
The forward flow volume across the main pulmonary artery was calculated in all patients and was significantly lower in group I than in group II, in group I with mean 42.42 ± 23.30 ml & in group II with mean 53.25 ± 28.46 %. The backward flow volume was higher in group I compared to group II with mean 20 ± 13.07 in group I & in group II mean 9.42 ± 10.66. RF was classified to mild (0-25%) in 27 patients, moderate (25-40%) in 8 patients & severe (>40%) in 5 patients. The regurgitation fraction of MPA & its branches was calculated in group I with mean 45.8 ± 9.7 & in group II with mean 9.8 ± 5.42 being significantly higher in group I (Fig 4).

Shunt assessment (QP/QS ratio)

Normally QP/QS ratio = 1, significant residual shunt was considered when QP/QS ration is more than 1.5 as QP represents pulmonary flow, QS represents systemic flow, 4 patients had QP/QS ratio > 1.5 in group I (3 of them post TOF repair, 1 patient post atrial switch TGA repair). Remaining 36 patients had average QP/QS ratio (ranged from 1-1.4), with statically significant difference between the two studied groups (P =0.018) with negative correlation between QP/QS ratio & RVEF (r=-0.383).

Case No. (1)

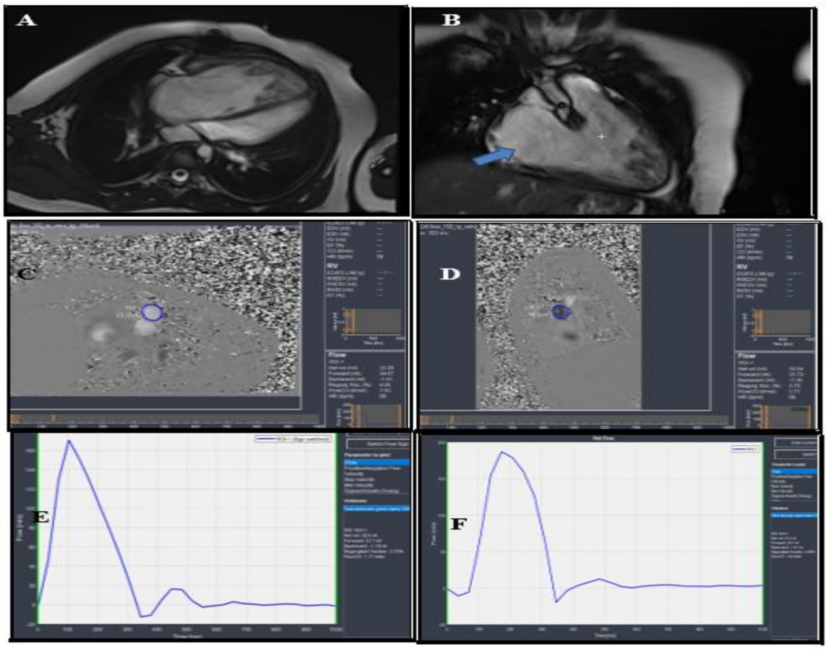


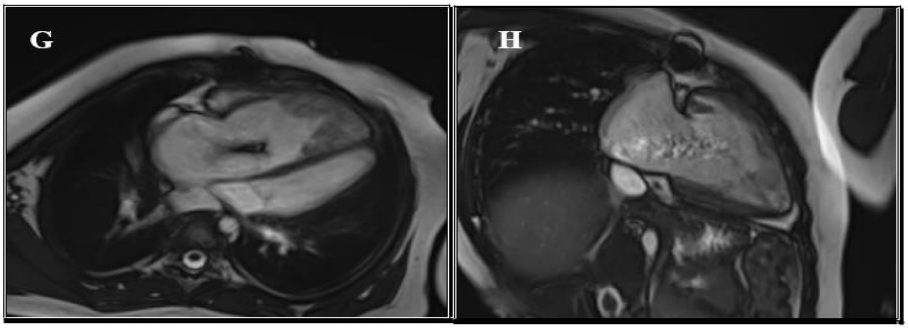


A 17-year-old male patient post TOF repair. Cardiac MRI axial SSFP cine images revealed: (A) Dilated pulmonary patch, (B) Dilated RVOT (blue arrows), (C) LPA branch stenosis (red arrow), (D) A jet of PR (black arrow), (E) 4-chamber cine image showing dilated RV, (F) Dilated MPA (4.2 cm), (G) LGE image showing enhancement at RVOT patch denoting fibrosis, (H) flow measurement across MPA with RF=34% denoting moderate pulmonary regurgitation, preserved RV function (RVEF =56%).

(TOF: tetralogy of Fallot, SSFP: steady state free precession, RVOT: right ventricular outflow tract, LPA: left pulmonary artery, PR: pulmonary regurgitation, RV: right ventricle, MPA: main pulmonary artery, LGE: late gadolinium enhancement, RF: regurgitation fraction, RVEF: right ventricular ejection fraction).

Case No. (2)





A 7-year-old female patient with history of TGA underwent mustard operation. CMR SSFP cine images: (A) 4-chamber view showing markedly dilated and hypertrophied RV, (B) RVOT view with aneurysmal dilatation of RVOT (blue arrow). (C-F) phase contrast views showing measurements of Pulmonary and aortic flows with flow curves (QP/QS =1) denoting no residual shunting. (G) 4-chamber cine image, (H) 2-chamber RV cine image showing jet of TR, RVEF =43%.

(TGA: transposition of great arteries, SSFP: steady state free precession, RVOT: right ventricular outflow tract, TR: tricuspid Regurgitation, RVEF: right ventricular ejection fraction).

Discussion

CMR is superior, more accurate & preferred than echocardiography due to its capability to identify intracardiac anatomical, functional, ventricular volume measurement especially in cases with large RV volumes & structural abnormalities, tissue characterization and postoperative complications following congenital heart diseases surgical procedures (5).

One of the most important prognostic features that can be detected & identified by CMR is myocardial fibrosis which is characterized by areas of late enhancement in gadolinium enhanced images, it has been shown that the presence and extent of late enhancement is predictive of arrhythmia and sudden death particularly in repaired TOF patients (6).

In our study patients with right ventricular dilatation & /or hypertrophy detected by CMR in 30 patients with statistically significant difference between both studied groups (P =0.039), only three of them developed RVF. This well matched with David et al[8], who concluded that only 2.9 % of patients developed significant postoperative RVF in a study conducted on 3.826 patients underwent cardiac surgery for correction of congenital heart diseases.

In this study, there was no statically significant difference between the studied groups regarding their ECG findings (P = 0.079), no previous studies conducted correlating between CMR RVEF & ECG changes. Periklis and Lim [9] conducted study on 85 patients with TOF and healthy volunteers for assessment of ventricular volume and function by CMR, found that TOF patients had higher RV EDVI (P<0.001), RV ESVI (P<0.001) and lower RV EF (P <0.001) compared to control group.

In agreement with our study, Ordovas et al [10] studied 143 patients with TOF following surgical repair concluded that the most encountered complication detected by CMR in patients with repaired TOF in the three surgical methods were recurrent or residual VSD, branch pulmonary artery stenosis, kinking of left pulmonary artery & RVOT patch aneurysmal dilatation. After TOF repair, most patients in the current study developed pulmonary regurgitation and this leaded to RV dilatation &dysfunction, so reintervention is necessary with pulmonary valve replacement of these patients with RF (>25%) & EDV (>160 ml) due to high risk for arrhythmia and sudden death. This was in harmony with previous study performed by Oosterhoff et al [11] which was conducted as prospective follow up study on 71patients developed moderate PR and RV dilatation after corrected TOF, some of them (RVEDV>160 ml) underwent pulmonary valve replacement with significant improvement after valve replacement and reduction of RV volumes.

Current study included 11 patients with history of TGA; most of them (6 patients) underwent arterial switch operation with good postoperative RV function & less complications than those patients underwent atrial switch operations (mustard (3) and senning (2) procedures). This agrees with Vander Hulst et al [12] concluded that arterial switch is the procedure of choice for correction of TGA with less complications than atrial switch procedures.

Few complications detected by CMR in the present study after arterial switch in only one patient out of 6 patients including branch PA stenosis & neo pulmonary obstruction, while more complications after atrial switch included TR (4 patients), baffle leak & stenosis (1 patient), RVF (1 patient). This was in line with Tobler et al [13] study conducted on 61 patients after correction of TGA with arterial switch procedure, concluded that most patients (97 %) with no complications, only 3 % developed valvular dysfunction & PA stenosis. Also agree with Roos Hesselink et al [14] study conducted on 91 patients underwent mustard procedure concluded that the right ventricle unable to sustain the systemic circulation at long term follow up and the ventricular function is declined in 45% of patients.

D'udekem et al [15] study included 305 patients underwent Fontan procedure concluded that good outcome of patients with few patients developed failure or shunt stenosis, and this was compaitable to our study. On the contrary, Saraiya et al [16] studied 71 patients operated for different CHD concluded that there were no appreciable complications noted following DORV and single ventricle repair by Fontan, Glenn, MBT & PA banding procedures. Geiger et al [17] studied 10 surgically repaired TOF patients and 4 healthy subjects as a control, reported that strong regurgitation was noted in repaired TOF patients while there was no detectable regurgitation in the control group. As well as the peak systolic velocity of MPA was higher in TOF repaired patients than in controls.

François et al [18] studied 11 post TOF surgical repair patients and 10 healthy controls, found that significant pulmonary regurgitation in repaired TOF patients was noted in comparison to control group. Regarding to regurgitation fraction in branch pulmonary arteries, it was greater in LPA compared to RPA. This is matched with Kang et al [19] study on 22 patients after TOF repair, reported the same finding of higher regurgitation fraction of LPA in comparison to RPA with statically significant difference (P = 0.002).

The current study measured QP/QS ratio in all postoperative patients with significant residual shunting in some patients (12 patients) with QP/QS ratio >1.5. There was statically significant difference between studied groups (P= 0.018) with shunting more in patients with reduced RVEF. This was in agreement with Varaprasathan et al [20] reported that velocity encoded cine MR imaging assess severity of shunt lesions in postoperated patients with evident residual shunting if QP/QS higher than 1.5& these patients with fair ventricular function and volume overload, so this requires urgent surgical intervention.

This CMR study identified that 5 patients of post TOF repair showed delayed mural enhancement at LGE images at the anterior aspect of RVOT in patients with TOF repair with transannular patch & also delayed enhancement of RV free wall was detected in one patient denoting myocardial fibrosis & scarring. These patients showed low RVEF & high RV EDVI. There was no statically significant difference between both groups. This agreed with Oosterhoff et al [11] who demonstrated similar results that patients with delayed mural enhancement after TOF repair showed low RVEF (43%) and high RV EDVI (>175 ml /m2).

In our study, it was found that transannular patch repair showed the least RVEF & highest RVEDVI, ESVI in comparison to other two methods of surgical repair. Similar results were found as Geiger et al [17] concluded in the study conducted on 10 surgically repaired TOF that transannular patch repair affects hemodynamics with resultant pulmonary regurgitation &progressive RV dilatation.

Conclusion

Cardiac magnetic resonance imaging is an extremely useful imaging method for the evaluation of normal and abnormal findings after surgical repair. CMR is able to effectively identify post-procedural anatomical and functional intra- and extracardiac information, thus allowing accurate diagnosis of postoperative complications in most patients. This allows further intervention on a timely manner when deemed necessary for the well- being of the patient.

List of Abbreviations

ARVC: Arrhythmogenic right ventricular cardiomyopathy
BBSE: Black blood spin echo
CHD: Congenital heart diseases
CMR: Cardiovascular magnetic resonance imaging
ESV: End systolic volume
LGE: Late gadolinium enhancement
MRA: Magnetic resonance angiography
RV: Right ventricle
RVEDVI: Right ventricular end diastolic volume indexed
SSFP: Steady state free precession
TGA:Transposition of great arteries

Competing interests: The authors declare that they have no competing interests.

Ethics approval and consent to participate: This study was approved by the Research Ethics Committee of the Faculty of Medicine at Tanta in Egypt. Written informed consent was signed by all patients who participated in this study.

Consent for publication: All patients included in this research gave written informed consent to publish the data contained within this study. If the patient was less than 16 years old, deceased, or unconscious when consent for publication was requested, written informed consent for the publication of this data was given by their parent or legal guardian.

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Authors' contributions

Me: Shaimaa G Abdelreheem, I suggested and developed the research idea, reviewing literature, Data collection and analysis, perform statistical analysis, write and revise the manuscript, Prepare MRI cases and perform required measurements, prepare figures and tables.
All authors Ekhlas A Shaban , Al Siagy A Abd El-Aziz , Raghda G Elsheikh and Naglaa L Dabees read and approved the final manuscript.

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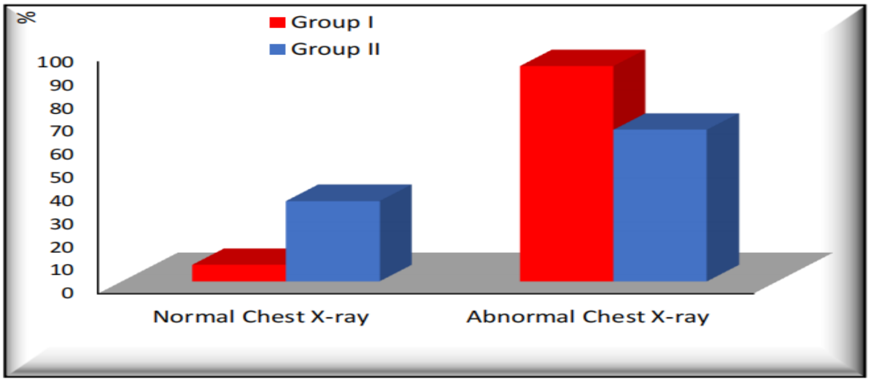

Fig 1: Comparison between studied groups according to chest X-ray abnormalities

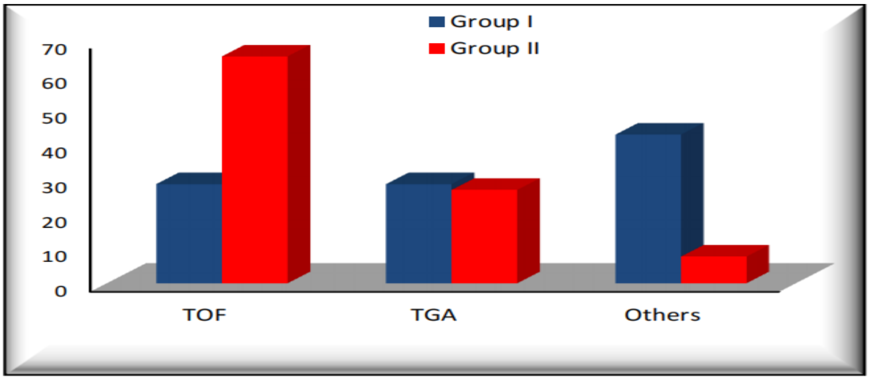

Fig 2: Comparison between two studied groups according to echo diagnosis.

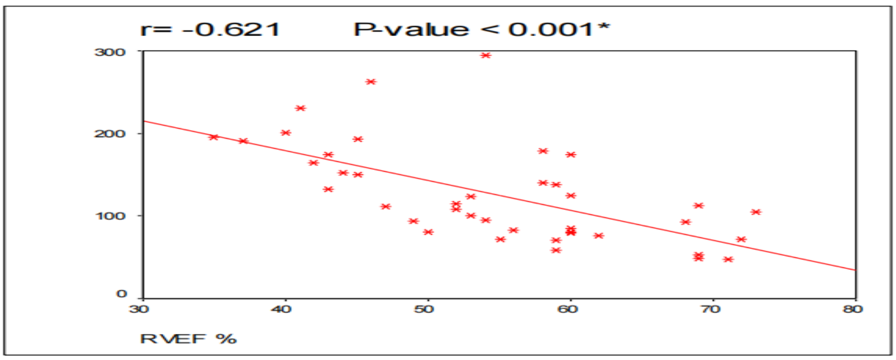

Fig 3: A scatter plot curve of correlation between RVEDVI & RVEF.

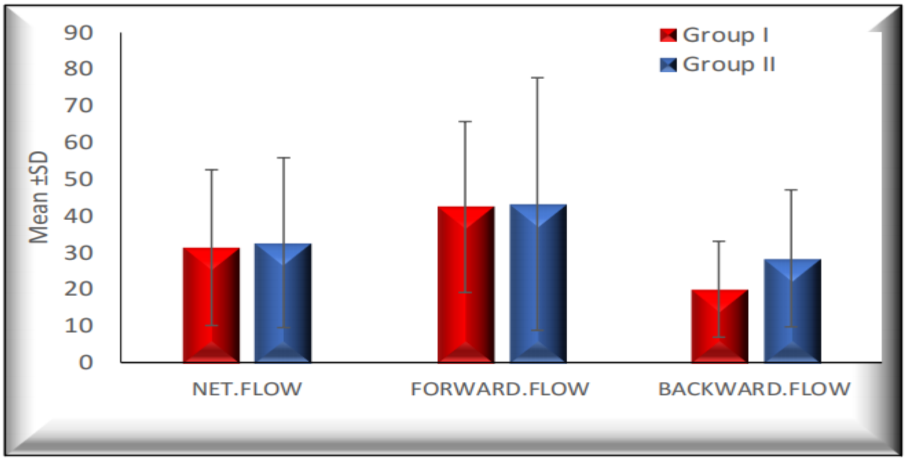

Fig 4: A plot showing flow measurements among the studied groups.

Figures titles and legends

Fig 1: Comparison between studied groups according to chest X-ray abnormalities.
Fig 2: Comparison between two studied groups according to echo diagnosis.
Fig 3: A scatter plot curve of correlation between RVEDVI & RVEF.
Fig 4: A plot showing flow measurements among the studied groups.

Procedure			
		N	%
TOF (Total repair)	Trans annular patch	5	27.78
	RVOT patch	3	16.67
	RV-PA conduit	10	55.56
TGA	MUSTARD	3	27.27
	SENNING	2	18.18
	Arterial switch	6	54.55
Others	MBT	3	27.27
	PA banding	2	18.18
	FONTAN	3	27.27
	Glenn	3	27.27

Table (1): Types of surgical repair of different CHD.

Type of surgical repair of TOF	RVEF (Mean %)	EDVI	ESVI
Transannular patch	48.7 ±7.5 %	164.5 ±50.12 ml /m^2	95.41±32.65
RVOT patch	56.21± 10.07 %	102±35.64	45.23±24.33
RV-PA conduit	50.8 ±9.05 %	92.56 ±26.12	40.36±18.05 ml /m^2
P value		0.003	0.04

Table (2): The relation between the method of surgical repair of TOF patients & RV volume and function

Type pf TGA repair	RVEF (Mean %)	EDVI Mean ml/m^2	ESVI Mean ml/m^2
Arterial switch	52.13 ± 9.82%	99.34±50.20	42.60 ±16.82 ml/m^2
Atrial switch	45.63 ± 4.56%	165.32 ±56.24 ml/m^2	90.78± 31.30 ml/m^2
P value		0.01	0.04

Table (3): The relation between the method of surgical repair of TGA patients & RV volume and function.

Complications			
		N	**%**
TOF	**Patch dilatation**	6	33
	PR	6	33
	Pulmonary branch stenosis	7	38.9
	Residual shunt	3	16
	RVF	1	6
	RVD +TR	6	33
TGA	**TR**	4	36.36
	RVF	1	9.09
	Baffle leak	1	9.09
	Baffle stenosis	1	9.09
	Residual shunt	1	9.09
	Neo pulmonary obstruction	1	9.09
	Branch PA stenosis	1	9.09
Others	**Pulmonary branch stenosis**	1	9.09
	Shunt stenosis	1	9.09
	Venous collaterals	1	9.09
	PA stenosis	1	9.09
	TR	1	9.09
	RVD, RAD	1	9.09

Table (4): Post-operative complications by CMR in selected CHD.

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Tables titles and legends

Table (1): Types of surgical repair of different CHD.
Table (2): The relation between the method of surgical repair of TOF patients & RV volume and function.
Table (3): The relation between the method of surgical repair of TGA patients & RV volume and function.
Table (4): Post-operative complications by CMR in selected CHD.