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ORIGINAL ARTICLE

Comparative Study Between Cardiac Magnetic Resonance Imaging and Echocardiography in Postoperative Evaluation of Fallot Tetralogy

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Abstract

Background: **Tetralogy of Fallot (TOF) represents the prevailing form of cyanotic congenital cardiac disease. Cardiac magnetic resonance imaging (CMRI) plays a crucial role in monitoring adult patients with congenital heart disease. Transthoracic echocardiography (TTE) is capable of providing the majority of the requisite data for sequential monitoring in patients with TOF.**

Aim: **To investigate the respective contributions of CMRI and echocardiography in the evaluation of postoperative Fallot tetralogy, using a comparative analysis.**

Methodology: **This study will be carried out on 30 cases of patients referred to the Heart Institute diagnosed with corrected TOF by surgery, followed by echocardiography and CMRI, as a comprehensive study between April 2022 and May 2023.**

Results: **Our study revealed that patient with postoperative Fallot repair revealed the following complications by ECHO and CMRI: Dilated RV with variable degree of affected function, residual pulmonary stenosis with or without its branches, pulmonary regurgitation, tricuspid regurge as well as residual ventricular septal defect shunt if present.**

Conclusion: **CMRI offers a notable benefit compared with transthoracic echocardiography due to its ability to precisely measure the size and function of both ventricles. CMR is widely regarded as the standard method for assessing volume and blood flow in cases with TOF, as well as residual pulmonary stenosis.**

Keywords: Cardiac magnetic resonance imaging, Echocardiography, Fallot tetralogy

1. Introduction

Tetralogy of Fallot (TOF) is a prevalent cyanotic congenital heart disease (CHD), with an estimated prevalence of 5/10 000 infants. The field of cardiac imaging has undergone significant advancements, transitioning from its reliance on cardiac catheterization and chest radiography to the utilization of more sophisticated imaging modalities such as echocardiography (ECHO), cardiac magnetic resonance (CMR), and cardiovascular computer tomography (CT).[1]

Although TOF is traditionally characterized by four distinct features, it is important to note that a significant number of patients also present with various additional abnormalities. These associated defects include branch pulmonary stenosis, which is observed in ~40% of cases, right aortic arch in 25% of cases, ascending aortic dilatation with or without aortic regurgitation in 15% of cases, atrial septal defect in 10% of cases, and anomalous coronary origin in 8% of cases, among other less common manifestations.

The majority of patients have undergone a comprehensive repair, which may eventually result in the anticipated occurrence of late pulmonary regurgitation (PR). This can lead to the dilation and impaired function of the right ventricle (RV).[2]

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The TTE serves as the primary and principal imaging modality for patients with TOF, both before and following surgical intervention.[3]

The prevailing approach in clinical practice is to utilize TTE as the primary modality for guiding initial therapeutic therapy. In a significant number of patients, TTE may suffice as the sole imaging technique for subsequent follow-up. Patients who exhibit substantial PR or aortic root dilatation should undergo annual TTE. However, asymptomatic patients with a straightforward clinical course may be monitored less regularly, with TTE conducted every two years.[4]

2. Patients and methods

This study will be carried on (30 cases) of patients referred to Heart institute diagnosed by corrected TOF by surgery, followed by ECHO and CMRI as comprehensive study between April 2022 and May 2023.

2.1. Inclusion criteria

Postoperative Fallot Tetrolgy investigated by both ECHO and MRI. Anesthesia will used in some patient.

2.2. Exclusion criteria

Contraindication to MRI e.g. patients with cochlear implant, cardiac pacemaker, electronic neuro-stimulants and foreign bodies.

2.3. Study design

Nonrandomized prospective cross-sectional study.

2.4. Equipment

This study will be performed using: ECHO examination by GE vivid IQ ultrasound machine and MRI examination by 1.5 T scanners (SIEMENS 1.5 TESLA).

2.5. The present study outlines the institutional protocol for cardiovascular magnetic resonance imaging (MRI) in patients who have had surgical correction for tetralogy of Fallot (TOF)

The localizers in the thorax pictures are used to represent morphological The evaluation can be performed with either the half Frequency shot turbo spin echo or balanced steady state free precession (SSFP) approaches, depending on the heart rate. These techniques are applied in the axial plane through the thorax. The morphologic examination is conducted using either the half Fourier shot turbo spin echo or balanced SSFP techniques, depending on the heart rate. This examination is performed in the axial plane through the thorax.

This study focuses on the dynamic evaluation of various constructions in two-dimensional planes. The initial view is decided by the axial morphologic perspective, followed by the subsequent. The subsequent view should be aligned in a perpendicular orientation to the initial cine image.

The structures under evaluation include the pulmonary arteries, including the main pulmonary artery (MPA), right pulmonary artery, and left pulmonary artery, as well as the RV outflow tract, ascending aorta, and ventricular septal defect. The utilization of 4-chamber SSFP cine views is recommended in order to comprehensively assess the RV. Additionally, a mid short axis SSFP cine image is suggested for evaluating septal movement or the entirety of the left ventricle in cases when left ventricular dysfunction is suspected. This study includes the acquisition of a 3-chamber SSFP view and a short-axis SSFP view of the aortic root to assess the aortic root and valve.

Additionally, a magnetic resonance angiography of the pulmonary artery was performed. This study focuses on flow mapping of the pulmonary arteries, namely the MPA, right pulmonary artery, left pulmonary artery, and the ascending aorta. The optional technique of myocardial delayed enhancement.

2.6. The following is a checklist for the examination of reports in magnetic resonance imaging (MRI) following postoperative tetralogy of Fallot (TOF) procedures

The concept in question is symbolized by The topic of discussion pertains to PR, specifically focusing on the quantification of regurgitation fraction as well as the quantification of RV volume and function, Incorporating both end-systolic volume and end-diastolic volume, along with the ejection fraction.

The evaluation of tricuspid regurgitation encompasses the quantification of many parameters, such as the dimensions of the right atrium, as well as the measurements of the MPA and the RV outflow tract. The assessment of the localization, extent, and severity of stenosis or aneurysm/dyskinesia in the right outflow tract is conducted, which involves the measurement of these conditions.

The evaluation of conduits calcifications and stenosis involves assessing their specific location, extent, and severity. This assessment includes measuring and quantifying the degree of stenosis, as well as determining the PR fraction and assessing the function of the RV. The evaluation of pulmonary artery stenosis encompasses the determination of its precise location, extent.

The objective of this study is to evaluate the position and magnitude of residual ventricular septal defects and quantify the shunt using the ratio of pulmonary to systemic blood flow (Qp/Qs). The evaluation of aortic root dilatation and aortic regurgitation encompasses several key aspects. Firstly, the assessment of aortic root dilatation involves the measurement of relevant parameters to determine the extent of enlargement. Additionally, the quantification of regurgitation fraction is crucial in determining the severity of aortic regurgitation. Lastly, the quantification of left ventricular volume and function is essential in evaluating the impact of these conditions on the functioning of the left ventricle.

2.7. Risks and ethical considerations

Any potential risks that may arise throughout the course of the research will be promptly communicated to both the participants and the ethics committee for clarification.

2.8. Statistical analysis

The data that was gathered was organized and examined using SPSS version 16 software, developed by Spss Inc, a company based in Chicago, Illinois. The categorical data were represented using numbers and percentages, while the quantitative data were portrayed using the mean ± standard deviation and range. The statistical methods employed for the analysis of categorical variables were the chi-square test (X2) and Fisher's exact test (FET). The normality of the quantitative data was assessed using the Kolmogorov-Smirnov test, with the assumption of normality at a significance level of *P* greater than 0.05. If the data were found to be regularly distributed, the Student's *t*-test was employed. In cases where the data did not follow a normal distribution, the Mann−Whitney *U* test, Kruskal-Wallis test, and Spearman's correlation coefficient (rho) were utilized. The predetermined level of significance in this study was established as 0.05 ($P < 0.05$ denoted significance). A *P* value greater than 0.05 was regarded nonsignificant (NS), while a *P* value less than 0.05 was deemed significant (S), and a *P* value less than or equal to 0.001 was classified as highly significant (HS).

Mean = the arithmetic mean of a dataset is obtained by dividing the sum of the values in the dataset by the total number of values. The symbol X, commonly referred to as X bar, is used to represent this quantity.

$$X = \frac{\sum X}{n}$$

In the context of this discussion, the symbol 'X' represents a variable denoting every given observation. The Greek capital letter '$\sum$' symbolizes the mathematical operation of summation, indicating the accumulation of values. Lastly, the variable '*n*' represents the total number of observations.

Standard deviation (SD): It is the positive square root of the variance.

Variance, denoted as S = 2, is a statistical measure that quantifies the dispersion of a series of measurements. It is computed by summing the squares of the deviations of each measurement from the mean of the series, and then dividing this sum by the total number of observations minus one. The concept of degrees of freedom.

$$S2 = \frac{\sum \text{Squared deviation of the mean}}{n-1}$$

$$S2 = \frac{\sum (X - X)\,2}{n-1}$$

$$\text{Chi square test } X2 = \frac{\sum (O - E)\,2}{E}$$

Where, O: is the observed value, E: is the expected value.

This analysis involves the comparison of two or more category groups, typically represented in the form of 2 × 2 or larger contingency tables.

FET is employed in situations when there are two nominal variables. The FET is considered to be a more precise statistical test compared with the χ^2test in situations where the anticipated frequencies are quite low.

The Student's *t*-test is a statistical test used to compare the means of two independent groups.

The *t*-value is defined as the ratio of the difference between the means of two groups to the standard deviation of this difference.

$$t = \frac{\overline{X1} - \overline{X}_2}{\sqrt{\frac{SD_1{}^2}{n_1} + \frac{SD_2{}^2}{n_2}}}$$

The location parameter X1 represents the arithmetic mean of group 1.

The variable X2 represents the mean value of the second group.

SD1 refers to the standard deviation of group 1.

SD2 refers to the standard deviation of group 2.

Let n1 represent the sample size of group 1.

The variable n2 represents the sample size of group 2.

The Spearman's correlation coefficient, denoted as rho, is a statistical measure used to assess the strength and direction of the linear relationship between two quantitative variables. In this context, one variable is considered the independent variable, denoted as X, while the other variable is the dependent variable, denoted as Y. The value of ‘r’ varies between −1 and 1, with 0 indicating no linear correlation, 1 representing a perfect positive correlation, and −1 indicating a perfect negative correlation.

3. Results

The data acquired underwent a process of revision, coding, tabulation, and introduction into a personal computer utilizing the Statistical Package for Social Science (SPSS 23).

3.1. Descriptive statistics

The mean, standard deviation (±SD), and range are often used measures for summarizing parametric numerical data. On the other hand, the median represents the middle value of a dataset when arranged in ascending or descending order is more appropriate for summarizing nonparametric numerical data. This study examines the frequency and proportion of non-numerical data.

3.2. Analytical statistics

Kappa statistics in order to determine the level of concordance between two investigative methodologies, it is necessary to calculate the measure of agreement. A kappa value beyond 0.75 can be considered exceptional, while a value ranging from 0.40 to 0.75 can be regarded as fair to good. Conversely, a kappa value below 0.40 is indicative of poor agreement. The *P* value is a measure of the level of significance in statistical hypothesis testing. A *P* value more than 0.05 is considered nonsignificant (NS), whereas a *P* value less than 0.05 is considered significant (S).

The distribution of the studied group regarding sex is 16 male of 53.3% and 14 female of 46.7%.

The distribution of the studied group regarding sex is 53.3% male and 46.7% female.

The above table revealed the comparison between studied groups by ECHO and MRI regarding residual pulmonary artery stenosis with detected 13 (43.3%) patient regarding by ECHO and 23 (76.7%) patient regarding by MRI as positive results.

Regarding the agreement between MRI and ECHO in the detection of residual pulmonary artery stenosis (as MRI was the gold standard detection tool), 66.7% of patients were agreed between the two tools as true negative were 7 (100%) patient of and true positive were 13 (56.5%) patient. This was a poor significant agreement as the Kappa value was 0.378 and *P* value was less than 0.05.

The above table revealed the comparison between studied groups by ECHO and MRI regarding pulmonary valve regurge and their grading with detected 27 patient regarding 90% by ECHO (3.7% mild, 18.5% moderate, and 77.8% sever) as well as detected 30 (100%) patient regarding by MRI as positive results (10% mild, 50% moderate, and 40% sever).

Regarding the agreement between MRI and ECHO in the detection of pulmonary valve regurge (as MRI was the gold standard detection tool), 90% of patients were agreed between two tools as true negative were 0% and true positive were 27 (90%) patient of.

The above table revealed the 43.3% agreement between ECHO and MRI at Pulmonary valve regurge PR grading (0% agreement between MRI and ECHO at mild degree, 23.08% agreement at moderate degree and 83.33% at sever degree).

The above table revealed the comparison between studied groups by ECHO and MRI regarding RV function with detected: impaired function [three (10%) patient at each ECHO or MRI], fair function [10 (33.3%) patient at ECHO and 16 (53.3%) patient at MRI] and good function [17 (56.7%) patient at ECHO and 11 (36.7%) patient MRI.

The above table revealed the 36.7% agreement between ECHO and MRI at RV function (0% agreement between MRI and ECHO at impaired function, 37.5% agreement at fair function and 45.5% at good function).

The above table revealed the comparison between studied groups regarding RV pressure by ECHO and MRI. The mean value of RV pressure regarding 39.77 by ECHO and 31.38 by MRI (Tables 1−9 and Figs. 1−8).

Table 1. Demographic data for the study group.

	Mean/*N* (SD/%)		Median (IQR)	Range
Age	22.20	13.01	21.5 (11−31)	(5−64)
Sex				
Male	16 (53.3)			
Female	14 (46.70)			

Table 2. Residual pulmonary artery stenosis for the study group.

	N (%)
ECHO	
No	17 (56.7)
Yes	13 (43.3)
MRI	
No	7 (23.3)
Yes	23 (76.7%)

Table 3. Agreement between MRI and echocardiography in residual pulmonary artery stenosis for the study group.

Residual pulmonary artery stenosis	MRI		%	Kappa	*P* value
	No [*N* (%)]	Yes [*N* (%)]			
ECHO					
No	7 (100)	10 (43.48)	66.7%	0.378	0.01 (S)
Yes	0	13 (56.52)			

Table 4. Pulmonary valve regurge pulmonary regurgitation and grading for the study group.

	N/Mean	%/SD	Median (IQR)	Range
ECHO				
No	3	10.0		
Yes	27	90.0		
Echo grading				
Mild	1	3.7		
Moderate	5	18.5		
Severe	21	77.8		
MRI				
No	0	0		
Yes	30	100.0		
MRI grading				
Mild	3	10.0		
Moderate	15	50.0		
Severe	12	40.0		
Regurgitation fraction	38.07	12.51	37% (32%–46%)	(10%–59%)

Table 5. Agreement between MRI and echocardiography in pulmonary valve regurge for the study group.

Pulmonary valve regurge	MRI		%
	No N (%)	Yes N (%)	
ECHO			
No	0	3 (10)	90.0
Yes	0	27 (90)	

Table 6. Agreement between echocardiography and MRI at pulmonary valve regurge pulmonary regurgitation grading for the study group.

Pulmonary valve regurge/ grading	MRI			Agreement %
	Mild *N* (%)	Moderate *N* (%)	Severe *N* (%)	
Echo				
Mild	0	0	1 (8.33)	43.3
Moderate	1 (50)	3 (23.08)	1 (8.33)	
Severe	1 (50)	10 (76.92)	10 (83.33)	

Table 7. Right ventricle function for the study groups.

	N/Mean	%/SD	Median (IQR)	Range
ECHO				
Impaired	3	10.0		
Fair	10	33.3		
Good	17	56.7		
RV function MRI				
Impaired	3	10.0		
Fair	16	53.3		
Good	11	36.7		
Systolic function	51.80	6.00	51 (48–56)	(40–62)

Table 8. Agreement between echocardiography and MRI at right ventricle function for the study group.

RV function	MRI			Agreement %
	Impaired *N* (%)	Fair *N* (%)	Good *N* (%)	
Echo				
Impaired	0	1 (6.3)	2 (18.2)	36.7
Fair	0	6 (37.5)	4 (36.4)	
Good	3 (100)	9 (56.2)	5 (45.5)	

Table 9. Right ventricle pressure for the study groups.

	Mean	SD	Median (IQR)	Range
ECHO	39.77	21.31	36 (25–47)	(13–100)
MRI	31.38	14.79	30.5 (20.5–36)	(16–73)

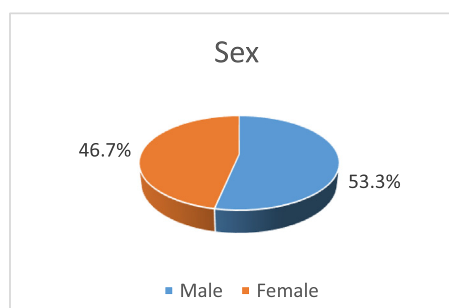

Fig. 1. Pie chart for the distribution of the studied group regarding sex.

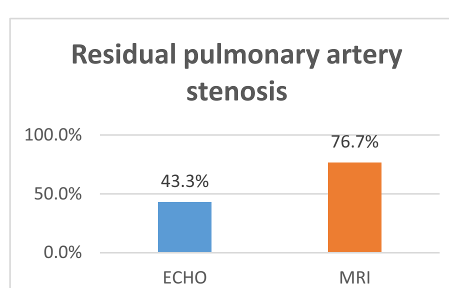

Fig. 2. Residual pulmonary artery stenosis for the study group.

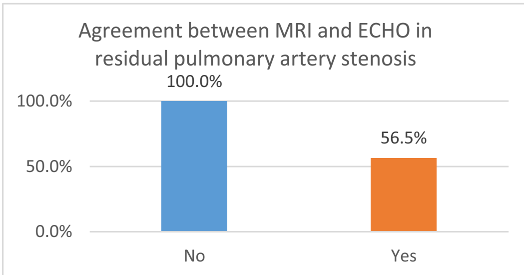

Fig. 3. Agreement between MRI and echocardiography in residual pulmonary artery stenosis for the study group.

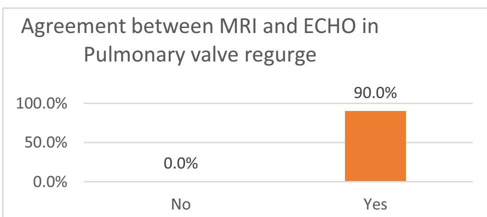

Fig. 4. Agreement between MRI and echocardiography in pulmonary regurge for the study group.

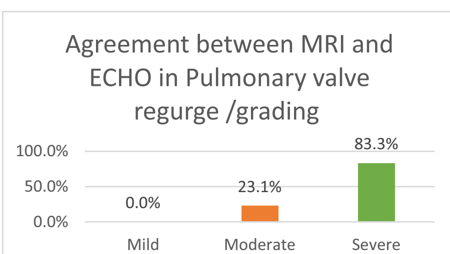

Fig. 5. Regarding the agreement between MRI and echocardiography in detection of pulmonary valve regurge grading.

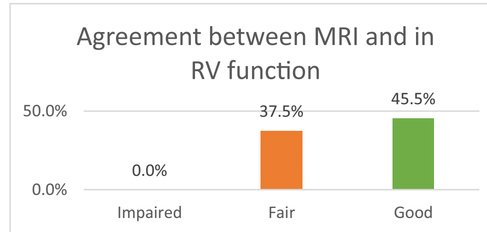

Fig. 7. Regarding the agreement between MRI and echocardiography in detection of right ventricle function.

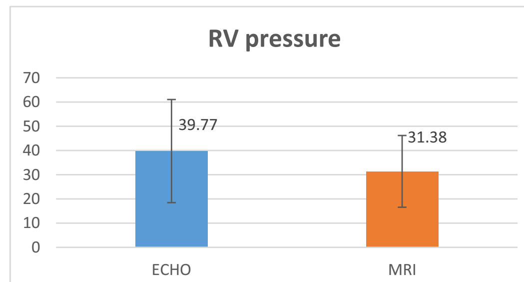

Fig. 8. The above figure revealed the comparison between studied groups regarding right ventricle pressure by echocardiography and MRI. The mean value of right ventricle pressure regarding 39.77 by echocardiography and 31.38 by MRI.

4. Discussion

TOF is a prevalent cyanotic CHD, with an estimated prevalence of approximately 5 per 10 000 infants. The field of cardiac imaging has undergone significant advancements, transitioning from its reliance on cardiac catheterization and chest radiography to the utilization of more sophisticated imaging modalities such as ECHO, CMR, and cardiovascular computer tomography (CT).[1]

CMR imaging plays a crucial role in the monitoring of adult patients with CHD. CMR imaging is

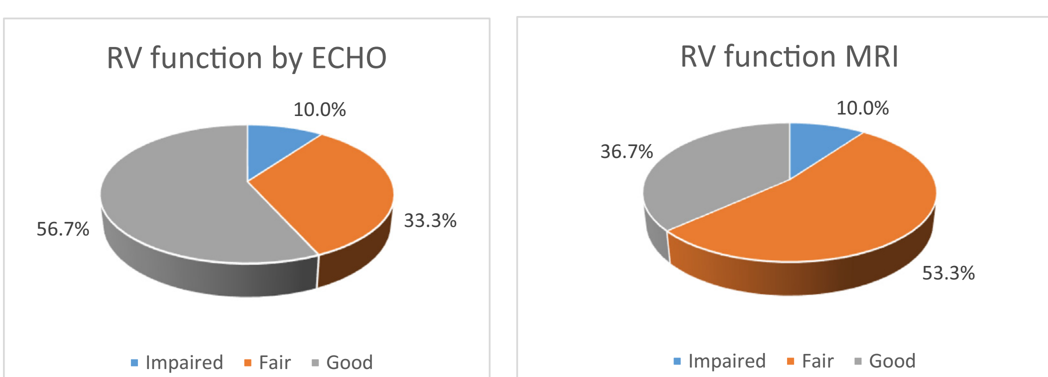

Fig. 6. Right ventricle function for the study groups.

recommended in various settings for serial follow-up in patients with TOF, as it can provide additional information beyond what is often obtained via TTE. When TTE exhibits unsatisfactory quality, when there is a conflict between TTE and clinical evaluation, for the purpose of tissue characterization, and as a potential substitute for invasive catheterization.[5]

In the current investigation, the distribution of the group under study with respect to sex is 53.3% male and 46.7% female with mean (22.2) and SD about 13% as shown in Table 1 and Fig. 1.

Regarding pulmonary valve regurgitation positive results at studied groups by ECHO and MRI there were: 27 (90%) patient regarding by ECHO (3.7% mild, 18.5% moderate and 77.8% sever) and 30 (100%) patient regarding by MRI (10% mild, 50% moderate, and 40% sever) as shown in Table 4 and the agreement (as MRI was the gold standard detection tool) 90% of the patients were agreed between two tools as true negative were 0% and true positive were 90% as shown in Table 5 and Fig. 4.

In agreement with the present result[6] the feasibility of quantitatively assessing the severity of PR in patients who have undergone repair for TOF has been demonstrated. This assessment can be achieved by a standardized ultrasound examination, which demonstrates a strong association with CMRI.

In agreement with the present result[7] the individual or individuals responsible for documenting the effectiveness of ECHO as a tool for evaluating RV function in postrepaired TOF with PR. The findings indicate a strong correlation between Fractional area changes (FAC), Tricuspid Annular Plane Systolic Excursion (TAPSE), and the severity of PR as determined by ECHO with the parameters obtained from CMRI.

In contrast with the present result[8] the individual who recorded the low capacity to quantify public relations (PR) in comparison to crisis management research CMR is not specified.

Regarding RV function at studied group by ECHO and MRI. The mean value of good RV function 17 (56.7%) by ECHO while 11 (36.7%) by MRI, The mean value of fair RV function 10 (33.3%) by ECHO while 16 (53.3%) by MRI. The mean value of impaired RV function 3 (10%) by each ECHO and MRI study as shown in Table 7 and Fig. 6 and the agreement (as MRI was the gold standard detection tool), 36.7% of patients were agreed between two tools as true positive were 45.5% good function, 37.5% fair function and 0% impaired degree as shown in Table 8 and Fig. 7.

In agreement with the present result[9] it has been observed that RV diastolic dysfunction is commonly found in individuals with TOF as indicated by measurements obtained using ECHO and cardiac MRI. The observed measurements exhibit a weak level of association with one another.

In agreement also with the present result,[8] it has been established that the ability to quantify RV function is reduced in comparison to CMRI.

In contrast with the present result[6] the feasibility of quantitatively assessing RV parameters in patients who have undergone repair for TOF has been demonstrated. This assessment is conducted using a standardized ultrasound examination, which has shown a strong association with CMRI.

In contrast with the present result[7] the individual or individuals responsible for documenting the effectiveness of ECHO as a tool for evaluating RV function in postrepaired TOF patients with PR. The findings of this study indicate a strong correlation between FAC, TAPSE, and the severity of PR as determined by ECHO and CMR characteristics. The most reliable criterion for predicting right ventricular end-diastolic volume index (RVEDVi) from CMRI is the measurement of area RVEDi obtained by ECHO.

Regarding residual pulmonary artery stenosis positive results at studied groups by ECHO and MRI there were 13 (43.3%) patient by ECHO and 23 (76.7%) patient by MRI as shown in Table 2 and Fig. 2 and the agreement (as MRI was the gold standard detection tool), 66.7% of patients were agreed between two tools as true negative were 100% and true positive were 56.5%.This was a poor significant agreement as Kappa value was 0.378 and P value was less than 0.05 as shown in Table 3 and Fig. 3.

4.1. Conclusion

CMRI offers a notable benefit compared with TTC due to its ability to precisely measure the size and function of RVs. CMR is widely regarded as the standard method for assessing volume and blood flow in cases with TOF, as well as residual pulmonary stenosis.

Conflicts of interest

There are no conflicts of interest.

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