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Correlation of Left Ventricular Function by 3-Dimensional Echocardiography and Cardiac MRI in Post-Operative Tetralogy of Fallot Patient: A Prospective Study

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KEYWORDS

(3D) echocardiography, CMRI, rTOF (Repaired Tetralogy of Fallot), LV dysfunction

ABSTRACT:

Background: Left ventricular dysfunction is one of the risk factors for adverse outcomes in repaired TOF (rTOF). Due to unfavorable RV-LV interaction in rTOF, it is warranted that sophisticated diagnostic techniques are used to recognize the early LV dysfunction which may affect the outcome. Cardiac MRI (CMRI) is the preferred method for assessing LV volumes and ejection fraction, due to its superior spatial resolution and comprehensive volumetric data. Meanwhile, three-dimensional echocardiography is currently being explored as a promising new technique.

Aim: To assess the efficacy of three-dimensional echocardiography as a means of evaluating left ventricular (LV) function in patients who have undergone repair for Tetralogy of Fallot (TOF), and compare its performance with that of CMRI.

Materials and Methods: 37 patients (mean age ± standard deviation [SD], 20.46 ± 9.4 years) who had undergone TOF repair were included in the study. 3 patients had suboptimal echo window, so only 34 patients had 3 D echo, while 37 patients underwent cardiac MRI. Four or six full volumetric 3D volumetric data sets were acquired from apical 4C views using the 1.5–3.6 MHz 3D probe with GE Vivid 7 Ultrasound System (GE Healthcare, USA) at a frame rate of 20– 30 frames/s. CMR examinations were performed on 1.5T clinical MR Scanner (CMR Signa/GE CV/i. Left ventricular end-diastolic volume (LVEDV) and ejection fraction (EF) were calculated by both methods.

Results: The prevalence of LV dysfunction in rTOF was evaluated using both Cardiac MRI and 3D Echo. According to Cardiac MRI findings, 45.9% of patients exhibited mild dysfunction, 35.1% had moderate dysfunction, and 5.5% had severe dysfunction. Similarly, based on 3D Echo results, 50% of patients showed mild dysfunction, 29.4% had moderate dysfunction, and 5.9% had severe dysfunction. The majority of patients, as observed through both Cardiac MRI and 3D Echo assessments, displayed mild to moderate LV dysfunction. The mean LV End Systolic Volume on Cardiac MRI was 73.42 ± 29.61 while the mean LV End Systolic Volume on 3D Echo was 67.32 ± 25.11. There was no significant difference in mean LV End Systolic Volume in Cardiac MRI and 3D Echocardiography (p-value = 0.36).

Conclusion: 3D echocardiography serves as a promising tool for assessing LVEF and LV volume in postoperative TOF patients. Future studies on larger populations are warranted to further validate these results.

Introduction

Tetralogy of Fallot (TOF) is one of the most common congenital heart defects associated with cyanosis and pulmonary under circulation, accounting for approximately 6%–10% of all cases of congenital heart disease. Over the years, advancements in tetralogy of Fallot (TOF) surgery have resulted in a significant enhancement of TOF survival rates. However, it is

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crucial for these survivors to undergo regular follow-ups due to potential complications such as arrhythmias, left ventricular (LV), and right ventricular (RV) dysfunction. While right RV dysfunction often occurs as a result of pulmonary regurgitation and RV dilatation, research has also highlighted LV dysfunction as a significant risk factor for adverse outcomes in individuals who have undergone tetralogy of Fallot (TOF) repair. (1)

Cardiac imaging, particularly cardiac MRI (CMR), plays a crucial role in monitoring patients who have undergone repair for Tetralogy of Fallot (TOF). By identifying and quantifying both anatomical and functional irregularities, CMR facilitates informed clinical decision-making and aids in risk stratification. It offers a comprehensive evaluation of cardiovascular morphology and physiology, regardless of acoustic windows, while avoiding ionizing radiation. However, limitations such as high cost, limited availability, and contraindications in patients with certain implants exist. (2)

The 3D echocardiographic method for assessing cardiac function in TOF patients has recently been described. The 3D Echocardiography is constructed by identifying the anatomical structure points on the 2D echocardiographic images to get a full 3D surface reconstruction.(3)

Although both these methods have been validated individually, they have not been compared in a clinical environment (4,5). The present study was conducted to compare and correlate the left ventricular function by 3D echo and cardiac MRI in post-operative TOF patients.

Patients and Methods

The Prospective observational cross-sectional study was conducted on 37 patients who underwent TOF repair, attending the Pediatric Cardiology clinic, Fortis Escorts Heart Institute, New Delhi between May 2021 to April 2023. The Patient ages ranged from 10 to 61 years with a mean age of 20.46±10.09 years. Patients with any known or detected arrhythmia interfering with image acquisition, those having contraindications for performing a cardiac MRI, and those who refused to participate in the study were excluded from the study. Informed consent was taken from parents/caregivers. Patients were consecutively selected after applying the relevant inclusion and exclusion criteria. Sample size calculation aimed to detect a moderate correlation (r = 0.60) between variables. A minimum sample of 20 analyzable subjects was determined to provide 80% power to discern significant correlation different from zero, at the 0.05 significance level.

CMR examinations were performed on 1.5T clinical MR Scanner (CMR Signa/GE CV/i. The Z score of left ventricular end-diastolic volume index volume (LVEDVi) and ejection fraction (EF) was calculated according to references values already published [Alfakih K et al]. LV dilatation is defined as LVEDVi Z value >2 and LV systolic dysfunction as LVEF Z value <−2.

3D echocardiography was conducted utilizing a 1.5–3.6 MHz 3D probe coupled with the GE Vivid 7 Ultrasound System (GE Healthcare, USA), operating at a frame rate ranging from 20 to 30 frames per second. Four or six full volumetric 3D volumetric data sets were acquired from apical 4C views. To mitigate inter-observer variability, a single observer independently assessed all patients using 3D echocardiography, and likewise, another single observer was responsible for assessing cardiac MRI scans.

LV dysfunction was defined as to American Society of echocardiography

LVEF > 55% -Normal

LVEF 45- 54% -Mild

LVEF 35-55% -Moderate

LVEF < 35% -Severe

Results

Out of total 37 patients 3 patients had suboptimal echo window on 3D Echo, so 3D Echo finding was done for 34 patients..

Table 1: Age wise distribution of study subjects (n=37)

Age group	Frequency	%
10-19 years	20	54.1
20-29 years	13	35.1
30-39 years	2	5.4
≥40 years	2	5.4

Mean ± SD	20.46±10.09 years
Min – Max	10-61 years
Median (IQR)	18 (13.5-24) years

Table 2: Gender distribution of patients

Sex	Frequency	%
Female	13	35.1
Male	24	64.9
Total	37	100

Table 3: Mean year since surgery

	Mean ± SD	Min – Max	Median (IQR)
Year Since Surgery	16.68 ± 6.36	9-39	15 (12-19.5)

Prevalence of LV dysfunction after TOF surgery in our study was specifically according to Cardiac MRI 45.9% had mild dysfunction, 35.1% had moderate dysfunction and 5.5% had severe dysfunction and according to 3D Echo 50% hadmild dysfunction, 29.4% had moderate dysfunction and 5.9% had severe dysfunction. So majority of patient both according to cardiac MRI and 3 D Echo had mild and moderate LV dysfunction

Table 4: Prevalence of LV dysfunction in patients after TOF surgery

LV Dysfunction	MRI (n=37)	3D Echo (n=34)
Normal (>55)	5(13.5%)	5(14.7%)
Mild (45-55)	17(45.9%)	17(50%)
Moderate (35-44)	13 (35.1%)	10(29.4%)
Severe <35	2 (5.5%)	2(5.9%)

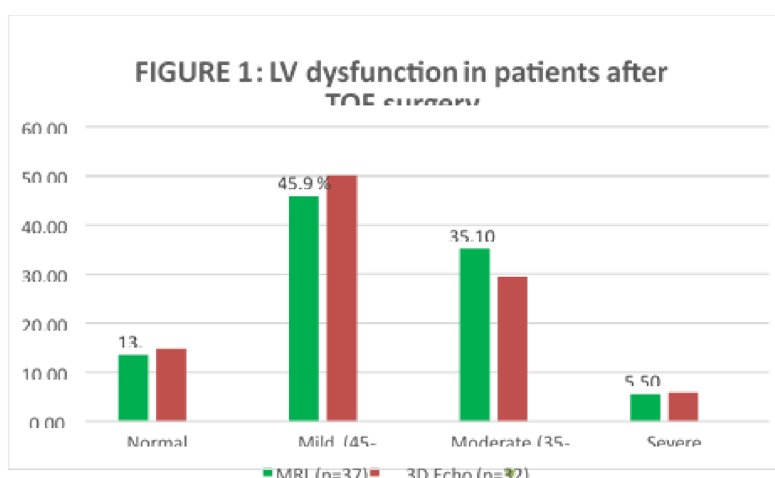

Table 5: Cardiac MRI Finding of the patients under the study

Cardiac MRI Finding	Mean ± SD	Min -Max	Median (IQR)
LV end diastolic volume (ml)	129.26 ± 35.15	79 - 244.0	116.5 (112.5 – 148.3)
LV End Diastolic Volume(ml/BSA)	84.87 ± 20.64	50.9-143	82.35 (71.2 - 92.50)

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LV End Systolic Volume(ml)	73.42 ± 29.61	37 – 163	67 (54-90.25)
LV End Systolic Volume(ml/BSA)	48.58 ± 17.23	27-94	45 (33.7-61)
LVEF (%)	43.88% ± 7.90%	30% - 62%	45% (36.5% - 50.2%)

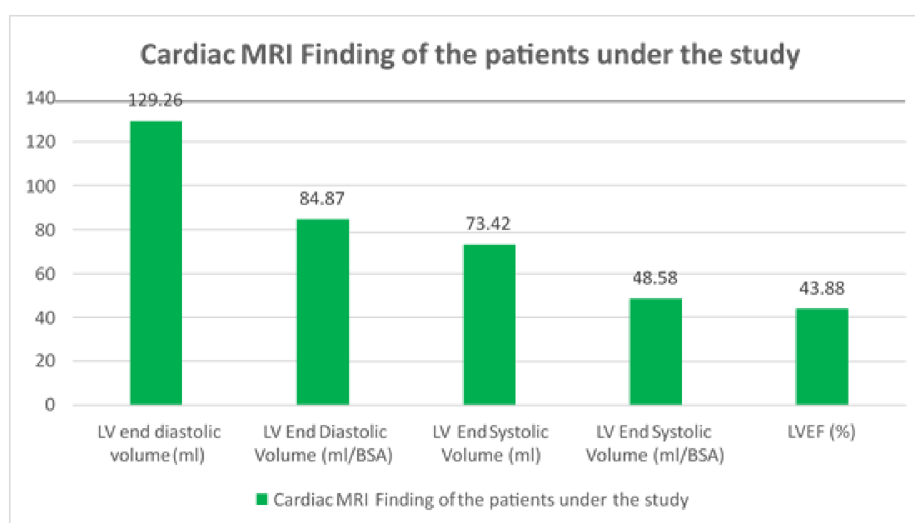

Figure 2: Cardiac MRI Finding of the patients under the study

The table and chart above show the mean Cardiac MRI Finding of the patients under the study. It was observed that mean LV end diastolic volume was 129.26 ± 35.15 ml with minimum 79 ml and maximum 244 ml while mean LV End Diastolic Volume was 84.87 ± 20.64 ml/BSA with minimum 50.9 ml/BSA and maximum 143 ml/BSA, mean LV End Systolic Volume was 73.42 ± 29.61 ml with minimum 37 ml and maximum 163 ml, LV End Systolic Volume was 48.58 ± 17.23 ml/BSA with minimum 27 ml/BSA and maximum 94 ml/BSA, mean LV EF was 43.88% ± 7.90% with minimum 30% and maximum 62%.

Table 6: 3D ECHO Finding of the patients under the study

3D ECHO Findings	Mean ± SD	Min – Max	Median (IQR)
End Diastolic Volume(ml)	124.88 ± 34.92	80 – 240	110 (106.50 - 140)
End Diastolic Volume(ml/BSA)	83.46 ± 19.30	53-138	82.3 (69.45-87.87)
End Systolic Volume (ml)	67.32 ± 25.11	32- 154	64.50 (50.12-83.25)
End Systolic Volume(ml/BSA)	43.94± 13.65	26.4-85	42.5 (32.42 - 53.12)
LV Ejection Fraction (%)	46.81% ± 8.48%	35% - 65%	48% (39.25% - 52%)

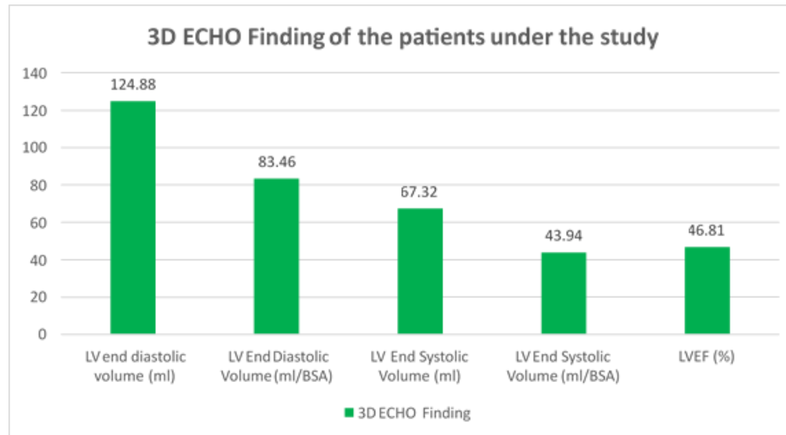

Figure 3: 3D ECHO Finding of the patients under the study

The table and chart above show the mean 3D ECHO Finding of the patients under the study. It was observed that mean End diastolic volume was 124.88 ± 34.92 ml with minimum 80 ml and maximum 240 ml while mean End Diastolic Volume was 83.46 ± 19.30 ml/BSA with minimum 53 ml/BSA and maximum 138 ml/BSA, mean End Systolic Volume was 67.32 ± 25.11 ml with minimum 32 ml and maximum 154 ml, mean End Systolic Volume was 43.94± 13.65 ml/BSA with minimum 26.4 ml/BSA and maximum 85 ml/BSA, mean LV Ejection Fraction was 46.81% ± 8.48% with minimum 35% and maximum 65%.

Table 7: Comparison of mean LVEF between Cardiac MRI and 3D Echocardiography

LVEF (%)	**Mean ± SD**	**Min - Max**	**Median (IQR)**	**p value**
Cardiac MRI	43.88% ± 7.90%	30% - 62%	45% (36.5% - 50.2%)	0.14
3D Echo	46.81% ± 8.48%	35% - 65%	48% (39.25% - 52%)	

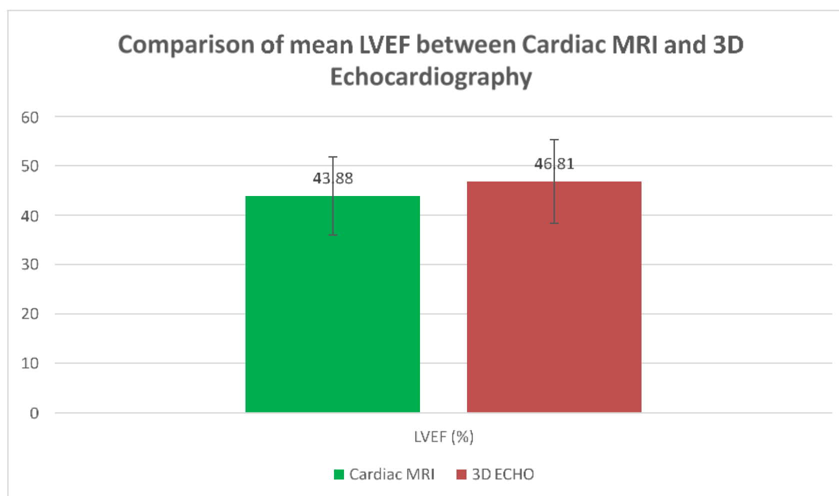

Figure 4: Comparison of mean LVEF between Cardiac MRI and 3DEchocardiography

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The table and chart above show the comparison of mean LVEF between Cardiac MRIand 3D Echocardiography. It was observed that mean LVEF in Cardiac MRI was 43.88% ± 7.90% with minimum 30% and maximum value 62% while mean LVEF in 3Echo was 46.81% ± 8.48% with minimum 35% and maximum value 65%. Further it was observed that little higher value of LVEF by 3D Echo compared to cardiac MRI and there was no significant difference when compared between mean LVEF inCardiac MRI and 3D Echo (p value 0.1)

Table 8: Correlation between Cardiac MRI and 3D Echo with respect toLVEF%

LV EF (%)		3D Echo
Cardiac MRI	Pearson Correlation	0.973**
	p value	<0.001**
	N	37

**** signifies highly significant p value<0.001**

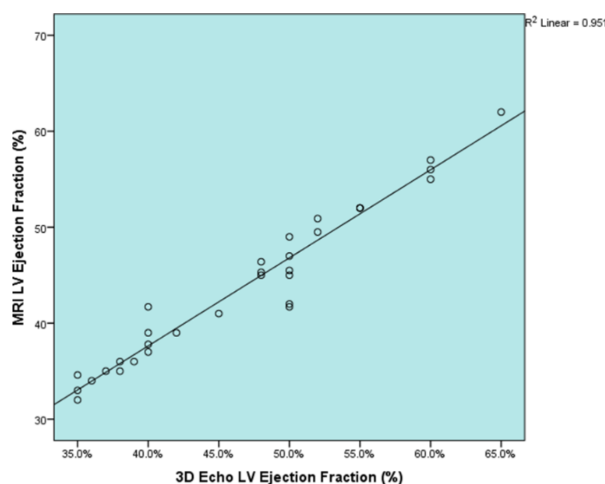

Figure 5: Scatterplot showing correlation between Cardiac MRI and 3D Echowith respect to LVEF%

It was observed that there was a significant positive correlation of LVEF% betweenCardiac MRI and 3d echo (r=0.965, p<0.001) in term of LV end systolic volume (ml).

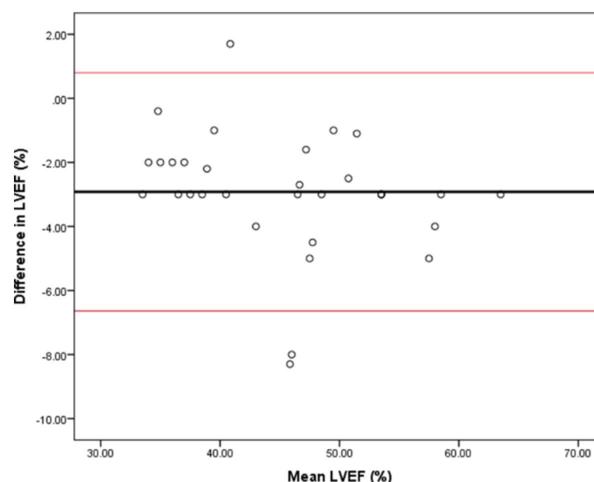

Figure 6 Bland Altman Plot showing the agreement between Cardiac MRI and3D ECHO with respect to LVEF (%)

The average of the differences of LVEF (%) was -2.92± 3.72. The limits of agreementestimated an interval of -6.64 to 0.80.

Discussion

The current study aimed to compare 3-D echocardiography versus cMRI in the assessment of left ventricular functions of patient who has TOF repair.

Mean Age of the patients was observed to be 20.46±10.09 years with a minimum age of 10 years and maximum age of 61 years., Li et al., 2013 included patients with a mean age of 23.6 ± 8.3 years [1]. Tzemos et al. [6] observed a comparatively higher mean age i.e., 31 ± 10 years. Mean age in Ait ali et al [7] study was age 30 ± 10 years. Andrade et al [5] total 103 patients were studied median age was 14.4 years: range, 1.3- 39 years. Mean BSA was 1.57± 0.24 m2 with minimum BSA 1.2 m2 and maximum BSA 2.1 m2. In present study, it was observed that majority of the patients (64.9%) were males whereas only one-fourth (35.1%) of the patients were females. Contrastingly, Tzemos et al [6] included an equal proportion of male and female patients]. Similar to our study Ait Ali et al [7] reported 58% male TOF subjects in their study.

In our study it was observed that mean year since surgery (TOF repair) was 16.68 ± 6.36 years with minimum 9 years and maximum 39 years. In study by Ait Ali et al [7], duration of Follow-up from intracardiac repair to CMR study was 24.1 years (range 18.7–31.1). Li et al.,

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2013 studied mean age of case was 18.8 ±7.4years following surgery and primary repair done at 4.9±3.7years.

Comparison of patients was done based on year since surgery and presenting complaints. It was observed that Mean year since surgery for patients with grade 1 was 14.5 ± 2.95 years while for patients with grade 2 was 16.17 ± 8.28 years and for patients with grade 3 was 18.83 ± 3.61 years.

Prevalence of LV dysfunction after TOF surgery in our study was specifically according to Cardiac MRI 45.9% had mild dysfunction, 35.1% had moderate dysfunction and 5.5% had severe dysfunction and according to 3D Echo 50% had mild dysfunction , 29.4% had moderate dysfunction and 5.9% had severe dysfunction.so majority of patient both according to cardiac MRI and 3 D Echo were have mild and moderate LV dysfunction , finding of our study were correlated with brobeerg , craig et al [8] as majority of patient in this study also had mild LV dysfunction they defined LV function as normal (LV ejection fraction >55%) or mild (45% to 54%), moderate(35% to 44%) or severely decreased (<35%) . 74(14.4%) had mild decreased and 33(6.3%) had moderately to severe decreased systolic LV dysfunction. However, of 511 patients studied, LV systolic dysfunction was present only in 107(20.9%). Andrade C et al [5] who observed no cases of severe dysfunction (LV EF <35%), 23% of cases showed moderate dysfunction (35% <LV EF <45%), 41% had mild dysfunction (45% <LV EF <55%), and 36% had normal LV EF. In contrast to our study, Anabtawi et al [4] reported LV function was moderately to severely reduce in majority of cases and prevalence of LV systolic dysfunction was 30%. Ait Ali et al [3] reported prevalence of LV systolic dysfunction, defined as LVEF Z value <−2, was 24 %. Ait ali et al choose to use the Z score value rather that the absolute values as in healthy subjects the ventricular volumes and EF varies according to the age class and gender.

Our study showed high prevalence of LV dysfunction in post operative TOF may be overestimated because sample size was less. Although another study also reported LV dysfunction in repaired TOF but sparse data regarding prevalence, but they reported LV dysfunction begin in childhood increased during stress. these studies also studied relation between RV and LV systolic dysfunction and described RV volume and pressure overload predispose to LV dysfunction and LV dysfunction is independent risk factor for poor outcome

In this study, on Cardiac MRI mean LV end diastolic volume was 129.26 ± 35.15 ml with minimum 79 ml and maximum 244 ml mean LV End Systolic Volume was 73.42 ± 29.61 ml with minimum 37 ml and maximum 163 ml, mean LV EF was 43.88% ± 7.90% with minimum 30% and maximum 62%. On 3D Echo mean End diastolic volume was 124.88 ± 34.92 ml with minimum 80 ml and maximum 240 ml, mean End Systolic Volume was 67.32 ± 25.11 ml with minimum 32 ml and maximum 154 ml, mean LV Ejection Fraction was 46.81% ± 8.48% with minimum 35% and maximum 65%.

So, there was no significant difference when compared mean LVEF, End Systolic Volume or end diastolic volume between Cardiac MRI and 3D Echo which shows that 3D Echo showed little lower values of LV systolic and diastolic volumes and higher values of LVEF compared to 3D MRI. Our study also supports the finding by Zhao D et al, 2021 that there was underestimation in LV end diastolic volume as measured by CMR as compared to 3D echo [56]. Dragulescu et al., 2012 also reported that 3D echo underestimated EDV by 18.2 ± 17.8 ml in paediatric patients as compared to MRI measurements [8]. Finding of our study were also in concordance with Benameur N et al [9] who also reported that a little lower values of LV volumes and higher values of LVEF was reported by 3D echo compared to CMRI.

Bland Altman Plot displayed the agreement between Cardiac MRI and 3D ECHO w.r.t Left ventricular End Diastolic volume (ml), Left ventricular End Systolic volume (ml) and Left ventricular End diastolic volume (ml). The average of the differences of LV End Diastolic volume (ml) was 6.05 ± 3.64. The limits of agreement estimated an interval of -1.09 to 13.17.

The average of the differences of LV End Systolic volume(ml) was 7.01 ± 8.47. The limits of agreement estimated an interval of -9.59 to 23.61. The average of the differences of LVEF (%) was -2.92± 3.72. The limits of agreement estimated an interval of -6.64 to 0.80. Although there is a consensus that 3D-echo underestimates LV volume when compared to CMR (10), there remain large discrepancies between the magnitude of reported underestimations (expressed as

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mean ± 2 SD), ranging from −4 ± 43ml (60) to −41 ± 37ml (61) for EDV, and 0 ± 33 ml (Z60) to −34 ± 45ml (62) for ESV. In study by Zhao D et al [11], the equivalent biases for EDV (−11 ± 50 ml to −18 ± 48ml) and ESV (−1 ± 30 to −9 ± 36ml). Finding of our study are also within the concordance of these studies. Benameur N et al [9] also reported strong correlation between the 3D echo and CMR in the measurement of functional parameters ($r = 0.96$ for LVEF values, $r = 0.99$ for ESV and $r= 0.98$ for EDV, $p < 0.01$ for all). Ait Ali et al [7] also found that LVEDVi and LVESVi correlated with LVEF ($p < 0.001$, $r = 0.28$; $p < 0.001$, $r = 0.3$) and reported that 23.6% patients had a reduced LV systolic function they also done LVEF STRAIN imaging and it was observed that mean GLS (%) was (-)14.84 ± 2.86 and mean GCS (%) was (-)16.63 ± 2.66 [3].

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References:

1. Abd El Rahman MY, Hui W, Yigitbasi M, Dsebissowa F, Schubert S, Hetzer R, et al. Detection of left ventricular asynchrony in patients with right bundle branch block after repair of tetralogy of Fallot using tissue- Doppler imaging-derived strain. J Am Coll Cardiol. 2005 Mar 15;45(6):915-21.
2. Adams CW. Bernheim effect (produced by an interventricular septal aneurysm following septal infarction). Diseases of the Chest. 1966 Dec;50(6):641-2.
3. American Heart Association Writing Group on Myocardial Segmentation and Registration for Cardiac Imaging: Cerqueira MD, Weissman NJ, Dilsizian V, Jacobs AK, Kaul S, et al. Standardized myocardial segmentation, and nomenclature for tomographic imaging of the heart: a statement for healthcare professionals from the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association. Circulation. 2002 Jan 29;105(4):539-42.
4. Anabtawi A,Mondragon J, Dodendorf D, et al. Late-stage left ventricular dysfunction in adult survivors of tetralogy of Fallot repair in childhood. Open Heart 2017;4:e000690. doi:10.1136/ openhrt-2017-000690
5. Andrade AC, Jerosch-Herold M, Wegner P, Gabbert DD, Voges I, Pham M, et al. Determinants of left ventricular dysfunction and remodelling in patients with corrected tetralogy of Fallot. Journal of the American Heart Association. 2019 Sep 3;8(17): e009618.
6. Tzemos N, Harris L, Carasso S, Dos Subira L, Greutmann M, Provost Y, et al. Adverse left ventricular mechanics in adults with repaired tetralogy of Fallot. The American journal of cardiology. 2009 Feb 1;103(3):420-5.
7. Ait AL, Trocchio G, Crepaz R, Stuefer J, Stagnaro N, Siciliano V, et al. Left ventricular dysfunction in repaired tetralogy of Fallot: incidence and impact on atrial arrhythmias at long term-follow up. The International Journal of Cardiovascular Imaging. 2016 Sep;32(9):1441-9.
8. Carr JC, Simonetti O, Bundy J, Li D, Pereles S, Finn JP. Cine MR angiography of the heart with segmented true fast imaging with steady-state precession. Radiology. 2001 Jun;219(3):828-34.
9. Benameur N, Arous Y, Ben Abdallah N, Kraiem T. Comparison Between 3D Echocardiography and Cardiac Magnetic Resonance Imaging (CMRI) in the Measurement of Left Ventricular Volumes and Ejection Fraction. Curr Med Imaging Rev. 2019;15(7):654-660
10. Wald RM, Haber I, Wald R, Valente AM, Powell AJ, Geva T. Effects of regional dysfunction and late gadolinium enhancement on global right ventricular function and exercise capacity in patients with repaired tetralogy of Fallot. Circulation. 2009 Mar17;119(10):1370-7.
11. Zhao D, Quill GM, Gilbert K, Wang VY, Houle HC, Legget ME, et al. Systematic Comparison of Left Ventricular Geometry Between 3D-Echocardiography and Cardiac Magnetic Resonance Imaging. Frontiers in cardiovascular medicine. 2021;20; 8:728205.