Al-Azhar International Medical Journal

Volume 5 | Issue 6 Article 45

7-1-2024

Section: Cardiovascular

Evaluation of Right Ventricular systolic function using Speckle Tracking Echocardiography versus Cardiac Magnetic Resonance in patients with repaired Tetralogy Of Fallot and its relation to functional Capacity

Abdelrahman Mohamad Sabry Elhadary
Cardiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt, Abdoooelhadary@gmail.com

Mohey Eldin Mansour Alabbady
Cardiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt

Kamal Ahmed Marghany
Cardiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt

Mohamed Abdelfattah Youssef
Radiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt

Mohammad Ismail Al-Deftar
Cardiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt

See next page for additional authors

How to Cite This Article

Elhadary, Abdelrahman Mohamad Sabry; Alabbady, Mohey Eldin Mansour; Marghany, Kamal Ahmed; Youssef, Mohamed Abdelfattah; Al-Deftar, Mohammad Ismail; and Mohamad, Reem Ramadan (2024) "Evaluation of Right Ventricular systolic function using Speckle Tracking Echocardiography versus Cardiac Magnetic Resonance in patients with repaired Tetralogy Of Fallot and its relation to functional Capacity," *Al-Azhar International Medical Journal*: Vol. 5: Iss. 6, Article 45.
DOI: https://doi.org/10.58675/2682-339X.2505

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Abdelrahman Mohamad Sabry Elhadary, Mohey Eldin Mansour Alabbady, Kamal Ahmed Marghany, Mohamed Abdelfattah Youssef, Mohammad Ismail Al-Deftar, and Reem Ramadan Mohamad

ORIGINAL ARTICLE

Evaluation of Right Ventricular systolic function using Speckle Tracking Echocardiography versus Cardiac Magnetic Resonance in patients with repaired Tetralogy Of Fallot and its relation to functional Capacity

Abdelrahman M. S. Elhadary [a,*], MoheyEldin M. Alabbady [a], Kamal A. Marghany [a], Mohamed A. Youssef [b], Mohammad I. Al-Deftar [a], Reem R. Mohamad [c]

[a] Department of Cardiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt
[b] Department of Radiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt
[c] Department of Radiology, National Heart Institute, Cairo, Egypt

Abstract

Background: ***After Tetralogy of Fallot correction, Cardiac Magnetic Resonance is the gold-standard technique for evaluating the right ventricle in patients. Despite its rising status as a tool for assessing ventricular function in relation to corrected TOF, research is still being done on speckle-tracking echocardiography (STE).***

Objective: ***After TOF repair, RV function is assessed using echocardiography in patients. The results are compared with those of the gold-standard CMR, and their functional capacity is inferred.***

Patients and Methods: ***Twenty-five patients (17 males) with repaired TOF were included. RV function was assessed using Echocardiography and CMR. Functional capacity was assessed by stress Electrocardiogram. The results of echocardiography, CMR, and functional capacity were correlated.***

Results: ***Among our patients, the average age was 18.2±7.6 years. A strong correlation was seen between the RV ejection fraction determined by CMR (r=0.459 P=0.020 and r=-0.403 P= P=0.045, respectively) and both fractional area change and myocardial performance index, in contrast to TAPSE and RVS velocity. A substantial correlation was found between CMR RVEF and STE and RV global and free wall strain. (r = 0.48 P = 0.01 and r = 0.53 P = 0.006, respectively). RV global strain was an accurate parameter in predicting RVEF≤50% and RVEDVi≥ 160ml/m² with good accuracy. RV strain is the only parameter correlated with functional capacity (r=0.53 P=0.005).***

Conclusion: ***RV Speckle tracking echocardiography can indicate RV systolic dysfunction and RV volume dilatation early on by measuring RVGLS ≤– 19% with high sensitivity and specificity. It is the sole parameter that is associated with functional capacity.***

Keywords: Tetralogy Of Fallot; Cardiac MRI; Speckle tracking echocardiography

1. Introduction

Tetralogy of Fallot (TOF) is thought to be the most prevalent cyanotic heart condition. It is characterized by four cardinal anomalies: right ventricular hypertrophy, aortic overriding, substantial nonrestrictive ventricular septal defect, and variable degrees of pulmonary stenosis, primarily infundibular .[1]

After undergoing thorough surgical correction of TOF, most patients develop varying pulmonary regurgitation (PR) levels, leading to right ventricular volume overload and dysfunction. Arrhythmias, abrupt cardiac death, and decreased functional capacity are further consequences .[2]

It is essential to regularly monitor and check the right ventricle in asymptomatic persons since malfunction can sometimes arise in the pre-clinical stage .[3]

Cardiac Magnetic Resonance (CMR) can reliably evaluate RV performance. However, recent research indicates that its correlation with patient prognosis could be better. Therefore, more precise criteria are needed to correctly identify patients who might be at risk of a decrease in proper ventricle function .[4]

Accepted 21 June 2024.
Available online 31 June 2024

* Corresponding author at: cardiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt. E-mail address: Abdoooelhadary@gmail.com (A. M. S. Elhadary).

https://doi.org/10.58675/2682-339X.2505

Novel tools for studying echocardiographic strain based on speckle tracking have recently become available. With the use of this technique, which offers precise data on the right ventricle's contractile function, it may be possible to test RV function more sensitively and identify RV dysfunction in the early stage in patients with repaired TOF .[5,6]

Furthermore, it was shown that whereas exercise capacity seemed to be an essential factor in detecting unfavorable sequelae in individuals with TOF, there was little correlation between exercise capacity and RV performance values generated from CMR. More sensitive RV performance indicators are required to enable the early identification of a reduction in RV performance. Recent research has shown that RV strain measurements obtained from echocardiography can offer this information.[6] In contrast to CMR, our goal was to evaluate the RV function in patients with corrected TOF using two-dimensional speckle tracking echocardiogram (2D-STE) and conventional echocardiography. After that, an evaluation of their functional ability regarding the results of the CMR and echocardiography is performed.

2. Patients and methods

Twenty-five individuals who had TOF repair as children were included in the current study. They were seen at Bab-Elshaaria University Hospital's outpatient clinic from July 2022 to December 2023.

All patients underwent clinical assessment, and we performed an electrocardiogram (ECG) to assess QRS width. Echocardiography was carried out utilizing a "Philips iE33 X Matrix" ultrasound equipment that used multifrequency (1 - 5 MHz) "S5-1" matrix array transducers (Philips Medical Systems, Andover, USA) fitted with STE technology. Image collection and processing required an ECG-gated examination. RV systolic function was evaluated using the following conventional parameters: myocardial performance index (MPI (Tie index)), fractional area change (FAC), right ventricular S-velocity (RVS-velocity), and tricuspid annular plane systolic excursion (TAPSE). By the most recent guidelines for post-Fallot imaging, 2D speckle tracking echocardiography (2D-STE) was performed on all patients .[7] A 1.5-Tesla system (Achieva, Philips, Best, The Netherlands) was used for CMR following guidelines to measure RV and LV volumes as well as indexed end-diastolic and end-systolic volumes (EDVi and ESVi), and PR fraction.[7] Stress ECG using standard Bruce protocol was done to assess functional capacity based on exercise duration.

SPSS_16.0.1 for Windows (Statistical Package for the Social Science; SPSS Inc.) was used to perform statistical analysis. Pearson's correlation coefficient and linear regression analysis were used to evaluate the relationships between RV FAC, tricuspid S', RV MPI, TAPSE, RV global longitudinal strain (RVGLS), and both RV ejection percent (RVEF) on CMR and RV volumes. To evaluate the efficacy of RVGLS in detecting RV dysfunction (RV EF <50%) and RV dilatation (RVEDVi>160ml/m²) in every patient, a Receiver Operating Characteristic (ROC) analysis was conducted.

3. Results

Baseline characteristics:
Seventeen patients (17/25) were male (68%) and eight (8/25) patients were female (32%). Our study's patient population was 18.2±7.6 years old on average. The ECG showed an average QRS length of 137 ± 17 ms.
Correlation between 2-D echocardiographic and CMR results:
Our study found that RVFAC, MPI, and RV global and free wall longitudinal strain (RVGLS and RVFWLS) were significantly correlated with RVEF measured by CMR, as shown in Figure (1). TAPSE and RVS` velocity showed no significant correlation with RVEF by CMR. Also, RVFAC and MPI were significantly correlated with RVEDVi, unlike strain analysis, TAPSE, or RVS` velocity. We found no correlation between any echocardiographic parameters and pulmonary regurgitation fraction (PRF) and LVEF by CMR. All these correlations are presented in Table 1.

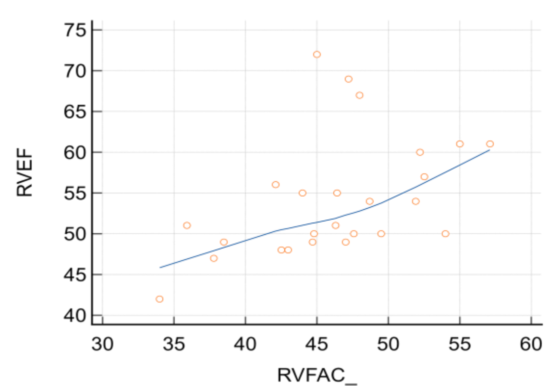


Figure 1. Significant correlation between RVEF measured by CMR and echocardiographic parameters.

Table 1. Correlation between CMR and Echocardiographic data

Echo / CMR	FAC	TAPSE	RVS` velocity	MPI	RVGLS	RVFWLS
RVEDVi	-0.4285 P=0.0326*	0.2391 P=0.2497	0.1451 P=0.4889	0.4179 P=0.0376*	-0.1418 P=0.4989	-0.2252 P=0.2790
RVEF	0.4598 P=0.0207*	-0.01004 P=0.9620	-0.07851 P=0.7091	-0.4032 P=0.0457*	0.530 P=0.0064*	0.4881 P=0.0133*
LVEF	0.2546 P=0.2194	-0.009204 P=0.9652	-0.03022 P=0.8860	0.1398 P=0.5052	0.1784 P=0.3937	0.2074 P=0.3198
PRF	-0.2954 P=0.1517	0.3617 P=0.0756	0.2545 P=0.2196	0.1347 P=0.5209	0.04324 P=0.8374	-0.04242 P=0.8405

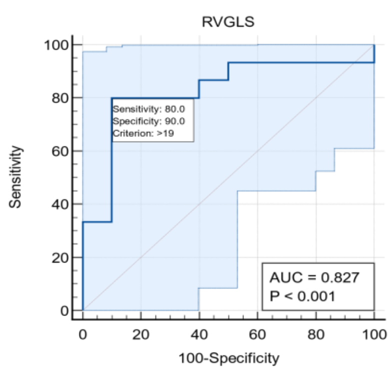
*: Indicates significant correlation

RV Speckle Tracking Echocardiography

The RVGLS is significantly correlated with CMR RVEF. Also, it is an accurate parameter in predicting RVEF≤50%. An RV GLS cutoff value of -19% was shown to have 81.8% sensitivity and 78.6% specificity in detecting RVEF ≤50% by receiver operating characteristics analyses (ROC), with an area under the curve of 0.812 (P = 0.001)Figure (2) B.

Also, the RVGLS is an excellent parameter for predicting RVEDVi≥ 160ml/m². An RV GLS cutoff value of -19% was shown to have 80% sensitivity and 90% specificity in detecting RVEDVi≥ 160ml/m² by receiver operating characteristics analyses (ROC), with an area under the curve of 0.827 (P < 0.001) Figure (2) A.

However, RVGLS has a low prediction for RVESVi≥80 ml/m². and LVEF by CMR≥55% P=0.07 and 0.44 respectively.



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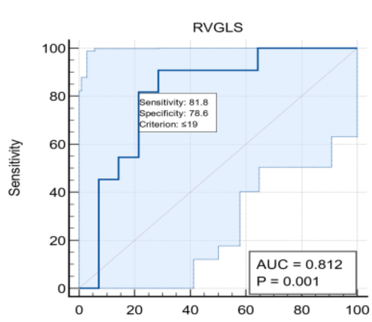

B

Figure 2. A:ROC for RVGLS and RVEDVi B: ROC for RVGLS and RVEF

Functional Capacity:

QRS duration and functional capacity showed a significant negative correlation, which means that with more prolonged QRS duration, there is a progressive decrease in exercise duration (P=0.02) (Figure 3).

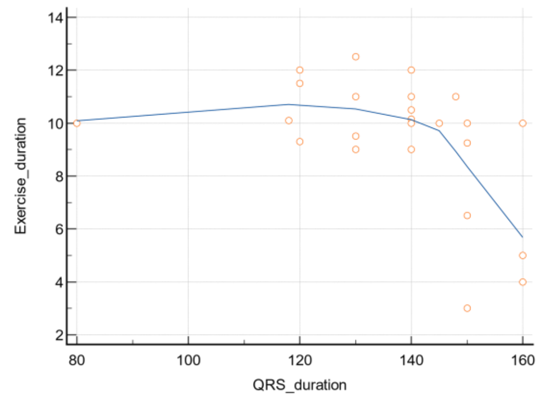

Figure 3. Correlation between QRS duration and exercise duration

Table 2. Correlation between CMR and functional capacity

Functional Capacity / CMR	***Exercise duration***
RVEDVi	***-0.1998 P=0.3383***
PRF	***-0.1967 P=0.3459***
LVEF	***0.07248 P=0.7306***
RVEF	***0.1808 P=0.3872***

As Table 2 shows, none of the RV parameters measured by CMR was correlated with functional capacity in our patients.

Only strain analysis with RVGLS and RVFWLS was correlated with functional capacity assessed by exercise duration. All other echocardiographic parameters, including TAPSE, FAC, RVS` velocity, and MPI, did not correlate with exercise capacity, as seen in Table 3.

Table 3. Correlation between 2-D echocardiography and functional capacity

Functional Capacity / Echo	**Exercise duration**
RVFAC	**0.3055 P=0.1375**
TAPSE	**-0.1931 P=0.3550**
RVS` velocity	**0.2522 P=0.2239**
MPI	**-0.3076 P=0.1346**
RVGLS	**0.5396 P=0.0054***
RVFWLS	**0.5695 P=0.0030***

* : indicates significant correlation

4. Discussion

Using multimodality imaging in patients with repaired TOF is a routine practice. Also, correlating their findings to patients' exercise capacity is essential to identify the threshold for timing intervention. In our work, The average QRS duration on ECG was 137 ± 17 ms in all patients, consistent with Kavurt et al.'s finding of 139 ± 24 ms .[8] Another study reported an abnormal average QRS complex duration of 126 ± 30 ms .[9]

Correlation between 2-D Echocardiographic and CMR results:

In our work, the CMR RVEF was significantly correlated with RVFAC, MPI, RVGLS, and RVFWLS. However, CMR RVEF and TAPSE or RVS` velocity were not correlated. This was in agreement with Li et al. In 56 individuals with TOF, it was discovered that TAPSE and RVS velocity did not show a correlation with CMR RVEF.[10] RVGLS was substantially linked with RVEF ($r = 0.64$, $P < 0.05$), which was similar to our finding .[10] Also, our findings were by Bao and his colleagues, who found that among 37 patients with repaired TOF, TAPSE, and RVS velocity showed no correlation with CMR RVEF. This discovery may be linked to the fact that TAPSE and RVS velocity do not account for the apex motion of the right ventricle. The fractional area change (FAC) showed a moderate correlation with the correct ventricular ejection fraction (RVEF) as measured by cardiac magnetic resonance imaging (CMR) with a correlation coefficient of 0.607. Also, RV-free wall longitudinal strain measured from four views correlated well with CMR RVEF. Bao and his colleagues did not assess the MPI of the RV in their patients.[11] Also, A different study found a strong link between CMR RVEF and FAC, with a correlation coefficient of 0.44 and a p-value of 0.003. However, there was no correlation between CMR RVEF and both TAPSE and RVS velocity.[4] Near to our results comparing CMR RVEF with MPI, Kavurt et al. found that MPI has a correlation with CMR RVEF but not reaching a significant level (r: −.37 P: .052) .[8] Our observation was (r: -.40 P=0.045). In our work, we found no significant correlation between PRF and any echocardiographic parameter, and this was in disagreement with Li et al. The study revealed an inverse correlation between PRF and RVGLS ($r = -0.48$, $P < 0.05$).9The fact that the cases in their study were younger may have contributed to this discrepancy (5.4±4.1 years) in comparison to our patients (18.2±7.6 years). Another study found that PR severity by echocardiography does not correlate with RV strain measured by tissue Doppler imaging. [12]

Accuracy of RV Speckle Tracking Echocardiography in prediction of RV dysfunction:

The best parameter we found to be linked with the RVEF was the RVGLS. With an area under the curve of 0.812 (P = 0.001), an RV GLS cutoff value of −19% exhibited 81.8% sensitivity and 78.6% specificity in detecting RVEF ≤50%, according to receiver operating characteristics analysis (ROC). This concurs with the findings of Toro et al., who discovered that an area under the curve for RV dysfunction (RVEF <45%) could be identified with 78% sensitivity and 77% specificity using an RV GLS cutoff value of −18%.87 (P<.001).[13] Also, Kavurt et al. discovered a strong correlation between CMR RVEF and RV GLS, with an area under the curve of 0.743 (P <.05) and a 75% sensitivity and 68.4% specificity for RVEF <45% when using an RVGLS threshold value of −17.4% .[8] This was in agreement with Toro et al who found that CMR RVEF has a good correlation with RVGLS (r=−.76, P<.001), and FAC as well (r=−.49, P<.001). Between CMR RVEF and TAPSE, there was no connection (r=-.02, P =.9). [13] Kavurt et al found a low correlation between CMR RVEF and TAPSE, RVS` velocity, and FAC (r: .41, r: .46, and 0.49, respectively, all P-value <.05). Additionally, they discovered a moderate association (r: -0.6, P <.05) between CMR RVEF and RVGLS.[8] Also, our observation was based on the findings of Li et al., which revealed that compared to patients with intact RVEF ≥45%, patients with corrected TOF and lowered RVEF had considerably lower RVGLS. However, our observed RVGLS was 19.9±4.4 (Mean ±SD), similar to their observation. This slight difference might be due to the difference in grouping the patients as we grouped our patients based on RVEDVi, not RVEF, measured by 3D echocardiography. They did not have CMR for their patients due to their relatively younger age (mean age: 4.7±2.3 years) .[5] Another study divided the patients based on CMR-derived RVEF less or more than 45% discovered that group I preserved RVEF of 45% (−20.9±3.3) had considerably higher RVGLS than group II's RVEF of < 45% (−15.3±3.8) (P<.001). [13]

Functional capacity:

QRS duration and functional capacity:

In our work, we found that QRS duration and functional capacity showed a significant negative correlation with P=0.02, and this was by another study that included 49 patients with repaired TOF and found that with an increase in QRS duration, there was a significant decrease in exercise capacity measured by bicycle stress test. [14]

Echocardiographic parameters and functional capacity:

In our work, only strain analysis with RVGLS and RVFWLS were correlated with functional capacity assessed by exercise duration. All other echocardiographic parameters, including TAPSE, FAC, RVS velocity, and MPI, did not correlate with exercise capacity. This agreed with another study that included 33 patients with repaired TOF and moderate to severe PR; they found that RVFWLS was the only parameter correlated with low functional capacity (METs<7). Additionally, they discovered that RVFWLS <17% (absolute value) might predict low functional capacity with an AUC of 0.785, sensitivity of 81.8%, and specificity of 77.3%.[15] The reduced ability to exercise in patients with corrected total occlusion of the heart was attributed to endothelial dysfunction as determined by flow-mediated dilatation of the brachial artery; this finding was uncorrelated with any traditional echocardiographic markers.[6]

CMR parameters and functional capacity:

Our research revealed no significant relationship between any CMR parameters and functional ability, which is consistent with the findings of another study that found 33 individuals with repaired TOF to have no significant relationship between CMR right ventricular measurements and exercise capacity.[15] This was also in agreement with O'Meagher et al., who could not find any CMR parameter that correlated with functional capacity in cardiopulmonary exercise testing in 55 patients with TOF repair either dilated or non-dilated RV volumes .[16] The absence of correlation between conventional CMR parameters, including volumes, the function of the RV, and the exercise capacity had been confirmed in another study. However, they found a correlation between feature tracking CMR-derived parameters and functional capacity .[17]

4. Conclusion

The study determined that patients who had undergone surgery for Tetralogy of Fallot (TOF) needed comprehensive imaging to evaluate the right ventricle's function accurately.

Significance of echocardiography: Not all traditional RV echocardiographic parameters are equally effective in evaluating RV function in TOF patients post-repair. FAC and MPI are more precise than TAPSE and RVS velocities. RV Speckle tracking echocardiography can indicate RV systolic dysfunction and RV volume dilatation early on by measuring RVGLS ≤– 19% with high sensitivity and specificity.

Cardiac MRI importance: Cardiac MRI cannot predict functional capacity as we could not find any correlation between cardiac MRI parameters and exercise duration.

Functional Capacity: Exercise testing using stress ECG standard Bruce protocol for repaired TOF patients is feasible and easy if cardiopulmonary exercise testing is unavailable.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

Funding

No Funds : Yes

Conflicts of interest

There are no conflicts of interest.

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