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Original Article

Echocardiographic Evaluation of Right Ventricular Function After Pulmonary Valve Replacement in Patients With Tetralogy of Fallot

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ABSTRACT

Background: Pulmonary regurgitation is a common complication after tetralogy of Fallot total correction (TFTC). Some of these patients may be candidated for pulmonary valve replacement (PVR) because right ventricular (RV) dysfunction will occur ultimately when a transannular patch has been used.

The aims of this study were to evaluate echocardiographic parameters in patients who underwent PVR after TFTC and to determine their outcomes in reference to their preoperative status.

Methods: Twenty-six patients with severe pulmonary regurgitation, who underwent PVR after TFTC with the transannular patch in Rajaie Cardiovascular, Medical, and Research Center, were enrolled. Some echocardiographic parameters were assessed before PVR and subsequently 1 and 3 months afterward.

Results: Of the echocardiographic parameters, the RV ejection fraction was significantly improved 1 month after PVR (P <0.001), while tricuspid annular plane systolic excursion (TAPSE) was not changed significantly at 1 month postoperatively (P = 0.27). TAPSE and the RV ejection fraction were increased significantly at 3 months postoperatively (P < 0.005). The myocardial performance index (MPI) in both left and right ventricles showed a statistically significant reduction 3 months after PVR (P < 0.001).

Conclusions: Our data showed that the RV ejection fraction changed early post PVR, while the changes in the MPI and TAPSE for both ventricles occurred later. Accordingly, these echocardiographic parameters should be evaluated and recorded serially in patients with TFTC. Additionally, these quantitative parameters should be assessed in the follow-up of patients after PVR. ***(Iranian Heart Journal 2017; 17(4): 42-48)***

Keywords: Pulmonary valve replacement● Pulmonary regurgitation● Tetralogy of Fallot● Tricuspid annular plane systolic excursion

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The surgical repair of tetralogy of Fallot has been performed for several years, with desirable early and long-term outcomes. Despite improvement in the operative techniques and early management in tetralogy of Fallot total correction (TFTC), the majority of the patients are exposed to chronic pulmonary regurgitation as a result of reconstructive surgery to relieve the obstruction in the right ventricular (RV) outflow tract. [1, 2]

Although it has been shown that the left ventricular (LV) function is usually well preserved after early TFTC, the RV volumes may increase and the ejection fraction (EF) may decrease. [3]

The severity of pulmonary regurgitation and the RV volume overload, as important postoperative adverse outcomes, is directly related to RV dilation and its role is known as a cause of arrhythmia and sudden cardiac death. [4]

A growing body of evidence demonstrates the clinical importance of the timely identification of deteriorating ventricular size and function after TFTC. Be that as it may, deciding when to perform pulmonary valve replacement (PVR) is a challenging issue for all congenital heart disease clinicians. [5]

Timely PVR can reduce RV volume overload and improve functional class and exercise capacity. PVR, therefore, has potentially favorable outcomes despite the high risks associated with it. [6]

Although cardiovascular magnetic resonance imaging (CMR) is considered the best and most accurate method for evaluating the RV size and function and quantification of PVR, it is expensive and not always available. On the other hand, echocardiography is more available and its cost makes it the 1st method of choice for this purpose, notwithstanding its poor performance in viewing the RV free wall and fractional area in comparison with CMR.[7, 8]

Echocardiographic assessment of the RV systolic function is, nevertheless, limited by the complex RV geometric shape. Other techniques such as M-mode-derived tricuspid annular plane systolic excursion (TAPSE) and the RV myocardial performance index (MPI) seem to be able to overcome these limitations.[9]

The aims of the present study were to evaluate some echocardiographic parameters of patients undergoing PVR after TFTC and to determine their outcome in reference to their preoperative status.

METHODS

Thirty-six patients with severe pulmonary regurgitation, candidated for PVR after TFTC with the transannular patch in Rajaie Cardiovascular, Medical, and Research Center, between 2014 and 2015, were enrolled. Based on the CMR data, the study population had an r > 165 mL/m^2 and an RVEF < 45%.

The exclusion criteria were death, embedded RV conduit to the pulmonary artery for TFTC, considerable residual defects (including ventricular septal defects, severe pulmonary stenosis, more-than-mild tricuspid regurgitation, and paravalvular leakage following PVR), and major arrhythmias. Seven patients were excluded with respect to these exclusion criteria. Transthoracic echocardiography was performed by an experienced cardiologist using a Vivid 3 (GE Vingmed Ultrasound AS, Horten, Norway equipped with a 3-MHz transducer). All the measurements were made in 3 cardiac cycles, and the averages were used for the statistical analyses.

For each patient, echocardiography was performed immediately prior to PVR and then 1 and 3 months afterward. Echocardiographic indices, namely TAPSE, RVEF (the Simpson 1-plane method), and the MPI (MPI for both ventricles), were assessed. In the apical 4-chamber view, the RV end-diastolic and end-systolic diameters were traced and the RVEF was calculated via the Simpson method. TAPSE was assessed via the M-mode (Fig. 1). The MPI was evaluated by using Doppler modality in the apical 5-chamber view for the LV and in both 4-chamber view and parasternal short-axis view for the RV. The average of the 3 measurements was recorded for each echocardiographic parameter (Fig. 2). The QRS duration in the ECG trace was also evaluated in all the patients before PVR and subsequently 1 and 3 months afterward. Other demographic characteristics of the patients as well as clinical signs and intraoperative data such as operation duration and the type of the valve (mechanical or bioprosthetic) used in PVR were recorded and analyzed. All the surgical operations were performed by 3 experienced pediatric cardiac surgeons and in an almost similar anesthetic situation. The local research ethics committees approved the study, and all the subjects (and/or a parent/guardian) gave written informed consent.

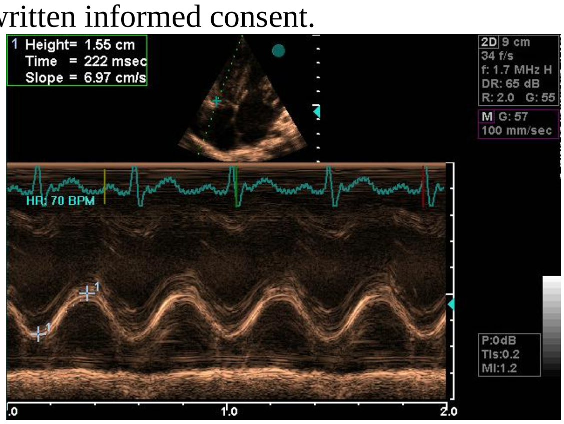

Figure 1. Tricuspid annular plane systolic excursion (TAPSE) in the lateral apical 4-chamber view by M-mode.

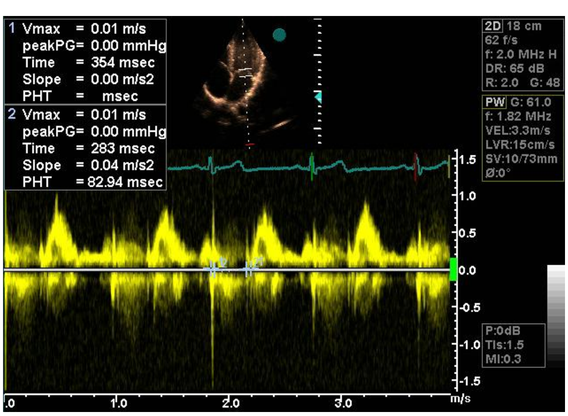

Figure 2. Myocardial performance index (isovolumic contraction time + isovolumic relaxation time /ejection time).

RESULTS

Twenty-nine patients at a mean age of 11.8 years (range = 6.4–18.9 y), comprised of 14 male and 15 female individuals, were prospectively studied before PVR and subsequently 1 and 3 months afterward. The baseline and surgery-related characteristics of all the patients are depicted in Table 1. As is shown in Table 2, among the echocardiographic parameters, the RVEF was significantly improved 1 month after PVR ($P < 0.001$), whereas TAPSE was not changed significantly at 1 month postoperatively ($P = 0.27$). The QRS duration exhibited no statistically significant change within a month after surgery ($P = 0.08$).

The changes in the echocardiographic parameters were significant in the 3rd postoperative month (Table 3). The RVEF and TAPSE were increased significantly at 3 months postoperatively ($P < 0.005$). The MPI in both ventricles showed a statistically significant reduction 3 months after PVR ($P < 0.001$).

In ECG, the QRS duration was reduced significantly at 3 months postoperatively.

The correlation between the echocardiographic parameters and age and time interval between TFTC and PVR are depicted in Table 4. Age correlated significantly with TAPSE 1 month after PVR ($r = 0.563$; $P = 0.001$) and with TAPSE 3 months after PVR ($r = 0.589$; $P = 0.005$). The time interval between TFTC and PVR had a significant correlation with TAPSE 1 month after PVR ($r = 0.511$; $P = 0.005$) and with TAPSE 3 months after PVR ($r = 0.515$; $P = 0.004$). The other echocardiographic variables had no significant correlations with age and the time interval between TFTC and PVR.

Table 5 shows the correlation between the RVEF and the QRS duration. There was an inversely significant correlation between the RVEF 1 month after PVR and the QRS duration ($P < 0.05$), while there was no significant correlation between the RVEF and the QRS duration 3 months after PVR (*P*>0.05). The correlation between the RVEF and TAPSE can also be seen in Table 5.

There was no significant correlation between the RVEF and TAPSE (*P* > 0.05).

Table 1. Baseline and surgery-related characteristics of all the patients

Variables	M±SD / N (%)
Age (y)	11.8±2.6
Sex (female/male)	15/14
Time interval between TFTC and PVR (y)	8.02±2.49
Clinical signs	
Resting dyspnea and fatigue	10 (34.5%)
Exertional dyspnea and fatigue	19 (65.5%)
Type of valve used in PVR	
biological	11 (37.9%)
mechanical	18 (62.1%)
Cardiothoracic ratio on CXR	
normal	0 (0%)
top normal	1 (3.4%)
increased	28 (96.6%)

PVR, Pulmonary valve replacement; TFTC, Tetralogy of Fallot total correction; CXR, Chest X-ray

Table 2. Echocardiographic parameters before and 1 month after PVR

	Before PVR	1 Month After PVR	*P*
QRS duration (msec)	160.86±17.27	159±16	0.08
TAPSE (cm)	1.51±0.16	1.48±0.15	0.27
RVEF (%)	41.37±4.12	45.06±16	<0.001

PVR, Pulmonary valve replacement; RVEF, Right ventricular ejection fraction; TAPSE, Tricuspid annular plane systolic excursion

Table 3. MPI and echocardiographic parameters before and 3 months after PVR

	Before PVR	3 Months After PVR	*P*
QRS duration (msec)	160.86±17.27	158±16	<0.001
TAPSE (cm)	1.51±0.16	1.58±0.12	0.005
RVEF (%)	41.37±4.12	48.3±2.9	<0.001
RV MPI	0.36±0.009	0.34±0.09	<0.001
LV MPI	41.37±0.01	0.39±0.01	<0.001

MPI, Myocardial performance index; PVR, Pulmonary valve replacement; RVEF, Right ventricular ejection fraction; TAPSE, Tricuspid annular plane systolic excursion

Table 4. Correlation between the echocardiographic parameters and age and time interval between TFTC and PVR

	Age		Time Interval Between TFTC and PVR	
	Pearson Correlation	*P*	Pearson Correlation	*P*
TAPSE 1*	0.563	0.001	0.511	0.005
RVEF 1*	0.051	0.79	0.141	0.46
RV MPI 2**	0.285	0.13	0.179	0.35
LV MPI 2**	0.257	0.17	0.333	0.07
TAPSE 2**	0.589	0.001	0.515	0.004
RVEF 2**	0.006	0.97	0.170	0.37

TFTC, Tetralogy of Fallot total correction; RVEF, Right ventricular ejection fraction; LV, Left ventricle; MPI, Myocardial performance index; TAPSE, Tricuspid annular plane systolic excursion

*: 1 month after PVR

**: 3 months after PVR

Table 5. Correlation between the RVEF and TAPSE and the QRS duration

	RVEF 1		RVEF 2	
	Pearson Correlation	*P*	Pearson Correlation	*P*
TAPSE 1*	0.255	0.18	0.142	0.46
TAPSE 2**	0.202	0.29	0.111	0.56
QRS duration 1*	-0.390	0.036	-0.311	0.10
QRS duration 2**	-0.447	0.015	-0.348	0.06

RVEF, Right ventricular ejection fraction; TAPSE, Tricuspid annular plane systolic excursion
*: 1 month after PVR
**: 3 months after PVR

DISCUSSION

One of the most frequently performed pediatric cardiac surgeries in our country is TFTC. This surgical modality can be accompanied by pulmonary insufficiency and progressive RV dilatation and dysfunction if it requires a transannular incision to relieve RV outflow obstruction. In the follow-up of these patients, the pediatric cardiologist should decide when to perform PVR, which is a seriously challenging decision. Recently in our country, an increasing number of pediatric patients with TFTC have undergone PVR. Given the significance of their medical follow-up, it is advisable that the simplest echocardiographic methods be employed because some echocardiography machines, especially those in remote areas, are not equipped with tissue Doppler and strain and strain rate software (latest techniques to evaluate the RV function).

Surgical PVR normalizes the RV dimensions, improves RV and LV contractility, and reverses the clinical symptoms. [10] A proper assessment of the severity of pulmonary regurgitation and the RV function is of great value in the follow-up of patients post PVR. Echocardiography plays an essential role in the longitudinal follow-up in these patients. [11]

After PVR surgery, most patients feel better because of improvement in their New York Heart Association's functional class. In most of the patients with an effective relief of pulmonary regurgitation, the RV volumes become normal and the RV performance (EF) improves significantly. [5] During our study period, the RVEF showed a considerable improvement among our patients, with the improvement manifesting itself even in the 1st postoperative month.

Currently, the evaluation of the RV shape is carried out using TAPSE. TAPSE has a significant correlation with the RVEF. [8] In our study, although TAPSE was changed significantly over time after PVR, we did not find any correlation between TAPSE and the RVEF. It could have been due to the low number of patients in our study. We also found a significant correlation between TAPSE and the time interval between TFTC and PVR. It seems logical that if PVR is performed before severe RV dysfunction develops, improvement in the RV function will be more possible.

The MPI, as a relatively newer Doppler technique, is a reliable method for the evaluation of the systolic and diastolic performances of both ventricles, particularly in congenital heart disease. In the current study, the MPI of both ventricles was reduced significantly 3 months after TFTC. Abdel Rahman et al [12] studied 50 patients who had TFTC and observed that those with severe pulmonary valve regurgitation who had a reduced RVEF showed a significant increase in the RV MPI.

QRS prolongation is a known marker of RV dilation, and a reduction in the QRS duration shows excellent freedom from arrhythmias after PVR. [6] In the current study, we demonstrated that the QRS duration was mainly allied to the RVEF and that the QRS duration decreased within 3 months after

surgery. A study by van Huysduynen et al [13] reported a reduction in the QRS duration 14 months after PVR, regarding improvement in the LV end-diastolic volume.
In summary, our data suggest that the MPI and TAPSE are reliable parameters for the evaluation of the LV systolic function. Thus, they may provide a quantitative tool to assess pulmonary regurgitation by echocardiography, although further validation is required to confirm the utility. Moreover, timely PVR, which prevents RV dilation, has a beneficial effect on the QRS duration

CONCLUSIONS

Echocardiography has a limited ability to quantify the RV function due to its complex geometry. Some patients after TFTC will need PVR; this is a scenario that is on the rise in pediatric patients. CMR is the gold standard for the evaluation of the RVEF and the RV end-systolic and diastolic volumes with a view to selecting patients for PVR after TFTC. In pediatric patients who have undergone PVR, echocardiographic evaluation of the RV function using TAPSE, RVEF by the Simpson method, and the MPI is valuable and simply accessible. We would, therefore, recommend that these simple and cost-effective modalities be utilized in the follow-up of these patients, especially when echocardiographic machines are not equipped with tissue Doppler and strain and strain rate modalities.

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Conflict of Interest: None.

Ethical Standards: This study was approved by our local ethics committee in accordance with the Helsinki Declaration of the World Medical Association (2000). All the patients provided written informed consent prior to the commencement of the study.

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