Mid-term results of patients following total surgical correction of tetralogy of Fallot

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The aim of this study was to evaluate the mid-term clinical status of patients following tetralogy of Fallot (TOF) repair.

We performed a cross-sectional observational analysis of 57 postoperative TOF patients and 58 age-matched controls. Patients were examined with myocardial performance index (MPI), which was obtained by tissue Doppler imaging (TDI) in addition to the conventional methods.

Compared with controls, patients had significantly higher right ventricular (RV) dimensions and volumes, RV MPI and left ventricular (LV) MPI, and significantly lower RV ejection fraction (EF), LV EF, exercise duration, and maximum heart rate with exercise ($p<0.001$ for all parameters). A positive correlation was found between RV MPI and LV MPI ($r=0.541$, $p<0.001$). There was a negative correlation between LV MPI and exercise duration ($r=0.260$, $p=0.034$).

After total surgical correction of TOF, the patients had a good clinical status at the mid-term follow-up; decreased exercise capacity and impaired functions in both ventricles related to the degree of pulmonary regurgitation were found. By using MPI, impaired cardiac functions can identify such conditions before they become clinically symptomatic.

***Key words:** tetralogy of Fallot, myocardial performance index, exercise test, postoperative follow-up, prognosis.*

Tetralogy of Fallot (TOF) constitutes almost 10% of congenital heart diseases and is also one of the most common forms of cyanotic heart diseases[1,2]. Cardiac function is of increasing importance for patients with operated TOF because life expectancy has been prolonged[3]. The systolic and diastolic functions in both ventricles may be altered after corrective surgery of TOF. Because of long-term problems such as ventricular dysfunction and pulmonary regurgitation (PR), reoperations may be required occasionally. The follow-up period of the patients is very important to determine the timing of the reoperations.

The aims of this study were to evaluate the mid-term clinical status of patients after corrective surgery of TOF, to determine any impaired cardiac function before it became clinically symptomatic, and to determine the relationship between the degree of PR and ventricular functions.

Material and Methods

Fifty-seven patients with TOF who were accessible at least one year after corrective surgery were examined with a cross-sectional observational study in a tertiary pediatric cardiology unit. Informed consent was obtained from the subjects' parents. The study protocol was approved by the medical ethics committee of our institution.

A complete physical examination was performed. A standard 12-lead electrocardiogram and 24-hour (h) ambulatory ECG (DMS 300-7 3-channel Holter recording device, NV, USA) were recorded to analyze spontaneous rhythm and QRS complex duration. Exercise testing (modified Bruce protocol) was performed in the patients and controls over five years old. The control group consisted of 58 age-matched normal children who were free from any cardiac disease according to history and physical examination. No evidence of structural cardiovascular disease was detected by echocardiography.

Echocardiographic Examination

Transthoracic echocardiography was performed using a Philips Sonos 5500 ultrasound system (Philips Medical Systems, Andover, MA, USA) with multifrequency transducers (3–5 MHz). Initially, routine diagnostic imaging was performed.

The systolic functions of both ventricles were measured in a 2-D image using modified Simpson method. In addition, end-systolic and end-diastolic diameters (ESD, EDD) were measured at middle levels and inlet of the right ventricle (RV) from the apical four-chamber view.

For the left ventricles (LVs) and RVs, the myocardial performance index (MPI), as has been reported previouslyFigure 1. Right and left ventricular MPI in patient and control groups.

(LVMPI: Left ventricular MPI. RVMPI: Right ventricular MPI)[4,5] was calculated as the sum of isovolumic contraction time (ICT) and isovolumic relaxation time (IRT) divided by ventricular ejection time (ET).

The spectral distribution of PR flow was assessed by color flow and pulsed wave (PW) Doppler in the left parasternal short-axis imaging. PR was assessed as grade 1 (trace) when regurgitant flow was detected below the pulmonary valve, grade 2 (mild) when it was detected at the level of the pulmonary valve, grade 3 (moderate) when it was detected in the pulmonary trunk, and grade 4 (severe) if the regurgitant signal was present at the pulmonary bifurcation[6].

The severity of tricuspid valve regurgitation (TR) was graded as the ratio of TR jet area to the right atrial area[7].

The measurements were made in five cardiac cycles, and the average was calculated for subsequent analyses. The Doppler tracing was recorded at the sweep of 100 mm/seconds (sec) and -20 to 20 cm/sec velocity interval, and stored on magneto-optic disc for later playback and off-line analysis. The same pediatric cardiologist performed all the echocardiographic examinations.

Statistical Analysis

Data analyses were performed using the Statistical Package for the Social Sciences (SPSS) 14.0 (Chicago, IL, USA). The results were reported as number (n) and percentage (%), mean + standard deviation (SD) and median (minimum–maximum) values. The Kolmogorov-Smirnov test was applied initially to check normal distribution. The categorical variables between the groups were analyzed using a chi-square test. For comparison of study variables between two groups, the T test or Mann-Whitney U test was performed. The assumption to calculate the correlation coefficient between numerical measurements was achieved by Pearson or Spearman correlations coefficients. The p values less than 0.05 were considered statistically significant for all parameters.

Results

Demographic and Clinical Data

The studied population consisted of 57 patients (31 males, 26 females) with TOF at least one year after corrective surgery and 58 age-matched healthy children (32 males, 26 females). The demographic characteristics of the patients and the control group are shown in Table I.

Before the corrective surgery, four patients underwent palliative Blalock-Taussig shunt. Twenty-four (46%) patients had a history of hypoxic seizure. Right ventricular outflow tract (RVOT) was primarily reconstructed by an infundibular resection and RV patch in all patients. In 30 patients, a transannular patch (TAP) was used, and 20 patients had no TAP. Hospital records of surgical data could not be located for seven patients.

The functional capacities of all patients were “class 1”, according to the New York Heart Association (NYHA) classification.

Rhythm Analysis

All of the patients were in sinus rhythm, and 84% of the patients (n=48) had right bundle

Table I. Demographic Characteristics of Patient and Control Groups

	Patient (n=57) Mean ± SD (median, range)	Control (n=58) Mean ± SD (median, range)	p
Age, years	7.9 ± 4.4 (6.6, 2.7 – 21)	7.5 ± 3.7 (7.6, 2.4 – 18.3)	0.596
Body weight, kg	25.9 ± 14.4 (20, 11 – 63)	27.5 ± 13.6 (24.3, 10 – 68)	0.544
Operation age, years	3 ± 2.3 (2.2, 0.8 – 11.8)		
Operation weight, kg	12.4 ± 4.6 (11, 7 – 30)		
Follow-up period after operation, years	5 ± 3.3 (4, 1.2 – 20)		

branch block. The QRS durations varied between 60–160 msec (mean: 120.3±21.6 msec, median: 120 msec). The Holter records of 44 patients (77%) were analyzed as normal. According to modified Lown criteria, 11 patients (19%) had grade 1 ventricular arrhythmia and 2 patients (4%) had sporadic supraventricular premature beat. None of the patients had complex ventricular arrhythmia.

Exercise Testing

Thirty-five patients and 32 of the control group underwent treadmill exercise testing. The mean exercise duration was 993.8±127 sec in the patient group and 1096±154.2 sec in the control group. The differences between the exercise durations were found to be statistically significant (p=0.005). Maximum heart rate was significantly lower (182.2±18 /min) in the patient group than control group (192.7±14.2 /min; p=0.01).

Echocardiographic Findings

The means of all RV dimensions were significantly larger in the patients than in the control subjects (p values <0.001 for all parameters) (Table II). When compared with controls, patients had greater RV dimensions, areas and volumes. RV ejection fraction (EF) was lower in patients than controls. LV end-diastolic areas and volumes were not different from controls, but end-systolic areas and volumes were significantly greater than in the control group. The EF value was calculated as ≤55% in 44 patients for the RV and in 14 patients for the LV (Table III).

In the patient and control groups, the differences between the means of RV ICT, IRT, ET, and MPI were significant (p<0.001, p<0.001, p=0.039, and p<0.001, respectively). While the differences in the means of LV ET were not statistically significant (p=0.160) between the patient and control groups, the means of ICT, IRT and MPI were significantly higher in the patient group (p<0.001) (Table IV, Fig. 1).

TR was detected in 45 (79%) patients, and was considered as mild in 30 cases and moderate in 15. In 12 cases, TR was not found or it

Table II. Right Ventricular Dimensions of Patient and Control Groups, Measured at Inlet and Midseptal

	Patient (n=57) Mean±SD (median, range)	Control (n=58) Mean±SD (median, range)	p
Inlet RV-EDD, mm	32.3 ± 4.9 (31.5, 22.3 – 50)	27.4 ± 4.8 (27.3, 17 – 39)	<0.001
Inlet RV-ESD, mm	26 ± 4.4 (25.6, 17 – 36.4)	21.2 ± 4 (22, 13.4 – 32)	<0.001
Midseptal RV-EDD, mm	36 ± 6 (35.7, 20.4 – 57)	30.2 ± 4.7 (30, 20 – 43)	<0.001
Midseptal RV-ESD, mm	28.3 ± 5.2 (28, 20 – 41)	22 ± 4.2 (22, 13 – 32)	<0.001

RV-EDD: Right ventricular end-diastolic dimension. RV-ESD: Right ventricular end-systolic dimension.

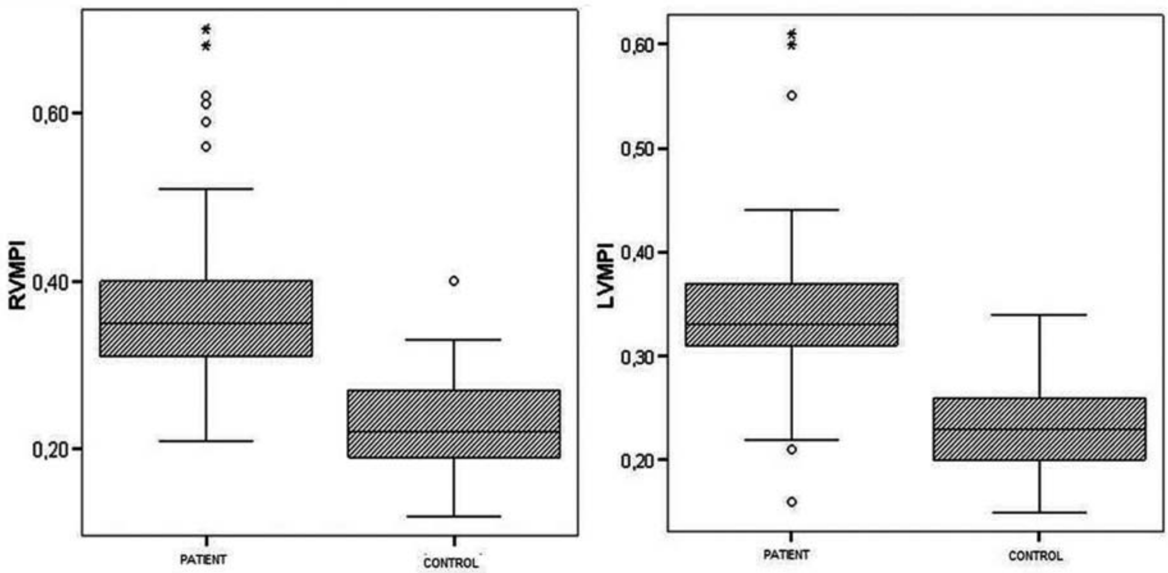

Figure 1. Right and left ventricular MPI in patient and control groups.
(LVMPI: Left ventricular MPI. RVMPI: Right ventricular MPI).

was within physiological limits. The maximum TR velocity ranged between 1.7 m/sec and 3.8 m/sec (mean: 2.4±0.41 m/sec, median: 2.4 m/sec). The gradient between the RV and pulmonary artery was found to vary between 4 mmHg and 57 mmHg (mean: 14.4±10 mmHg, median: 11.2 mmHg). The gradient between the RV and the pulmonary artery was >20

Table III. Right and Left Ventricle Systolic Function Parameters of Patient and Control Groups, Measured via Modified Simpson Method

	Patient (n=57) Mean±SD (median, range)	Control (n=58) Mean±SD (median, range)	p
RV-EDA, cm2	19.5 ± 7.2 (18.2, 9.2 – 44.5)	13.7 ± 3.8 (139, 7.1 – 23.5)	<0.001
RV-EDV, ml	52.8 ± 33.1 (45, 13 – 190)	30.8 ± 13.6 29.3, 10 – 73.6)	<0.001
RV-ESA, cm2	12.8 ± 5.2 (11.4, 5.9 – 36.1)	6.8 ± 2.4 (6.5, 3 – 16)	<0.001
RV-ESV, ml	28 ± 19.9 (23.4, 7.8 – 137)	11.1 ± 5.6 (10.2, 3 – 34)	<0.001
RV EF, %	47 ± 10 (47, 27 – 73)	64 ± 0.5 (64, 57 – 81)	<0.001
LV-EDA, cm2	17.2 ± 4.9 (16, 10.2 – 29.2)	16 ± 4.2 (15.3, 9.2 – 26.2)	0.171
LV-EDV, ml	40.6 ± 17.6 (35.4, 18.1 – 87.2)	37.6 ± 15.5 (33.9, 15.1 – 74.4)	0.335
LV-ESA, cm2	9.8 ± 3 (9.4, 5.8 – 18)	8.2 ± 2.7 (7.7, 4.2 – 15.2)	0.004
LV-ESV, ml	16.9 ± 8.3 (16, 7.5 – 42)	13.5 ± 6.2 (12, 4 – 29.5)	0.016
LV EF, %	59 ± 0.7 (60, 42 – 76)	65 ± 0.6 (63, 58 – 79)	<0.001

EF: Ejection fraction. LV-EDA: Left ventricle end-diastolic area. LV-EDV: Left ventricle end-diastolic volume. LV-ESA: Left ventricle end-systolic area. LV-ESV: Left ventricle end-systolic volume. RV-EDA: Right ventricle end-diastolic area. RV-EDV: Right ventricle end-diastolic volume. RV-ESA: Right ventricle end-systolic area. RV-ESV Right ventricle end-systolic volume.

mmHg in 13 patients; in just 2 cases, the gradient was >40 mmHg.

Pulmonary regurgitation (PR) was detected as trace in 2 (3%) patients, mild in 25 (44%), moderate in 29 (51%), and severe in 1 (2%).

No statistically significant relationship was found between the age at surgery and the QRS duration, RV MPI, LV MPI, exercise duration, or maximum heart rate during exercise.

While a positive correlation was determined between the postoperative follow-up period and the RV MPI (r=0.404, p=0.002), the same relationship was not found with LV MPI (r= - 0.021, p=0.879). There was a positive correlation between the follow-up period and the QRS (r=0.276, p=0.041) and exercise duration (r=0.414, p=0.015), but no relationship was found with the ratio of maximum heart rate achieved.

No relationship was found between QRS duration and RV and LV MPI. There was a positive correlation between the RV inlet and middle diameters at systole and diastole and QRS duration (r=0.300, p=0.028 for inlet RV-EDD; r=0.380, p=0.006 for inlet RV-ESD; r=0.320, p=0.020 for midseptal RV-EDD; r=0.460, p=0.001 for midseptal RV-ESD).

The difference between the PR grade of the patients who did and did not have TAP was statistically significant (p=0.032) (Table V). Since the group size was very limited, the patients with trace and severe PR were not included in this statistical analysis.

While there was a significant difference in RV ICT, ET and MPI between patients with TAP and those without, no difference was found in their IRT means. No difference was detected between the two groups according to their LV MPI, exercise duration and QRS duration (Table VI).

There was a borderline non-significant difference between the RV MPI of patients with mild PR grade compared with patients with moderate PR grade (p=0.06). The LV MPI of patients with mild PR grade was significantly lower than in patients with moderate PR grade (p=0.032) (Table VII).

No significant relationship was found between the RV MPI and EF in the patient group. However, a significant positive correlation was detected between the RV MPI and RV end-diastolic volume (EDV; r=0.450, p<0.001) and between the RV MPI and RV end-systolic volume (ESV; r=0.469, p<0.001). There was a positive correlation between the LV MPI and RV EDV (r=0.320, p=0.001).

No relationship was found between exercise duration and RV MPI (r=-0.159, p=0.203), but

Table IV. Right and Left Ventricular MPI Parameters of Patient and Control Groups

	Patient (n=57) Mean±SD (median, range)	Control (n=58) Mean±SD (median, range)	p
RV ICT, msn	62.9 ± 18.6 (60, 30 – 118)	32.3 ± 11.3 (30, 10 – 80)	<0.001
RV IRT, msn	40.2 ± 15.9 (35, 21.6 – 99)	28.5 ± 7.7 (30, 15 – 45)	<0.001
RV ET, msn	279.6 ± 33.1 (277, 203.3 – 363.3)	266.4 ± 34.3 (267.5, 170 – 345)	0.039
RV MPI	0.37 ± 0.1 (0.35, 0.21 – 0.70)	0.23 ± 0.03 (0.22, 0.12 – 0.40)	<0.001
LV ICT, msn	57.5 ± 15.9 (56, 20 – 90)	34 ± 9.1 (35, 18 – 67)	<0.001
LV IRT, msn	38.2 ± 10.4 (37.5, 20 – 73)	29.9 ± 7.5 (30, 15 – 45)	<0.001
LV ET, msn	282.9 ± 26.8 (285, 230 – 349.4)	275.3 ± 30.5 (282.5, 200 – 300)	0.160
LV MPI	0.34 ± 0.08 (0.33, 0.16 – 0.61)	0.23 ± 0.04 (0.23, 0.15 – 0.34)	<0.001

ET: Ejection time. ICT: Isovolumic contraction time. IRT: Isovolumic relaxation time. LV: Left ventricle. MPI: Myocardial performance index. RV: Right ventricle.

Table V. Relationship between Transannular Patch and Degree of PR

Degree of PR	TAP (+) (n=30)	TAP (-) (n=20)	Total (n=50)
Trace	1 (3.3%)	1 (5%)	2
Mild	10 (33.3%)	12 (60%)	22
Moderate	19 (63.3%)	6 (30%)	25
Severe	0 (0%)	1 (5%)	1

PR: Pulmonary regurgitation. TAP: Transannular patch.

a negative correlation was detected between exercise duration and LV MPI (r=0.260, p=0.034).

A positive correlation was detected between RV MPI and LV MPI (r=0.514, p<0.001).

Discussion

Cardiac performance is of increasing importance for patients with surgically corrected TOF because of prolonged life expectancy. This situation indicates the significance of postoperative follow-up and the methods to use during the follow-up period. Following total corrective operations, the functional capacity of patients was generally good. In long-term follow-up, the majority of patients are able to perform daily activities without any exercise limitation[8-10]. The exercise capacity of patients without severe PR or ventricular dysfunction is close to their healthy counterparts. Since these defects that develop after the surgery are progressive, their effects on the daily life of patients will occur in the later decades of their lives. In our study, the functional capacity of all patients was very good. This was an expected finding, since the follow-up periods of our patients were not very long and their average ages were relatively young.

Electrocardiogram monitoring is very important during the follow-up of operated patients. Arrhythmia, branch block, right atrial dilatation, and QRS duration can be evaluated via ECG. Many authorities have described electrocardiographic determiners for ventricular arrhythmia and sudden death[11-15]. In particular, a relationship has been demonstrated between QRS duration over 180 msn and RV dysfunction, malignant ventricular arrhythmia and sudden death[12-15]. In our study, none of the patients had QRS duration over 180 msn. A positive correlation was found between the postoperative follow-up period and the QRS duration. It is considered that, since the follow-up period of the patients was not long, the QRS durations were also not long. In our study, a positive correlation was shown between QRS durations and ESD and EDD. It will be convenient to measure and record the patient's QRS duration at every visit, and in case of an increase, to conduct further work-ups such as magnetic resonance imagine (MRI) to examine PR and the volume and functions of the RV, and in addition, to perform 24-h

Table VI. Relationship between Transannular Patch and ECG, Effort Test and Echocardiography Parameters

	TAP (+) n=30	TAP (-) n=20	p
RV ICT, msn	65.8 ± 16.8	53.9 ± 15.9	0.017
RV IRT, msn	40.6 ± 17.2	36.9 ± 12.4	0.400
RV ET, msn	268.7 ± 33.8	292.4 ± 25.6	0.011
RV MPI	0.40 ± 0.11	0.31 ± 0.07	0.001
LV MPI	0.34 ± 0.08	0.34 ± 0.07	0.880
QRS duration, msn	113.9 ± 24.1	124.8 ± 23.9	0.130
Exercise duration, msn	982.2 ± 146.8 (n=15)	996.0 ± 101.5 (n=14)	0.850

ET: Ejection time. ICT: Isovolumic contraction time. IRT: Isovolumic relaxation time. LV: Left ventricle. MPI: Myocardial performance index. RV: Right ventricle.

Table VII. Relationship between Right and Left Ventricular MPI and PR Degree

PR degree	n	RV-MPI Mean ± SD	p	LV-MPI Mean ± SD	p
Mild	25	0.34 ± 0.12	0.060	0.32 ± 0.08	0.032
Moderate	29	0.40 ± 0.11		0.36 ± 0.08	

Holter monitoring, since the incidences of arrhythmia will increase.

Despite normal RV size and volumes before surgery, it was reported that RV dilatation develops after surgery[16]. After TAP, chronic PR is universally present to some degree and well tolerated for many years, and is associated with dilatation and dysfunction of the RV. However, during surgery, resections in the RVOT disturb the balance of the RV and affect systolic functions[16]. Moreover, fibrotic changes on the myocardium exposed to high pressure and hypoxemia during surgery performed at older ages contribute to RV dysfunction[17]. In our study, the ESDs and EDDs were larger in the patient group than the control group. The larger measurements in the older patients might be due to fibrotic changes developing on the myocardium exposed to high pressure and hypoxemia before the surgery. Similarly, the diastolic and systolic volumes measured through the modified Simpson method were larger in the patient group than the control group, and the EF was found to be lower.

The complex geometric structure of the RV limits the evaluation of the RV systolic functions with standard techniques like 2D, M-mode echocardiography. Techniques such as radionuclide ventriculography, MRI, and 3D or 4D echocardiography are suggested in the evaluation of RV systolic functions[18-24]. Routine MRI measurements in all patients with TOF are not feasible due to the cost of the procedure and limited availability of centers trained in cardiac MRI studies. In our study, various echocardiographic techniques were used to evaluate the structure and the functions of the ventricle. Systolic functions of the RV were evaluated through the modified Simpson method, and as expected, the EF was found to be low in the patient group.

In recent years, it was reported that the MPI is useful in the evaluation of the functions of the global RV after surgery as well as in many other disorders. This index is very important, since it is not affected by blood pressure, tricuspid insufficiency or pulmonary hypertension[25]. However, it was also reported that in cases of PR in TOF following total corrective surgery, the MPI obtained by PW Doppler is not accurate for measuring the functions of the global RV, and therefore, PW tissue Doppler imaging (PW-TDI) is suggested to obtain a more accurate MPI in those cases.

Abd El Rahman et al.[3] studied the RV MPI by PW Doppler in operated patients with TOF and found the index was below normal values in most of the patients (76.5%). They claimed that RV with compliance disorder can decrease the IRT, and as a result, this MPI can be calculated paradoxically low. After this study, Yasuoka et al.[26] calculated MPI in postoperative patients with TOF via both PW Doppler and PW-TDI, and then compared them to each other and the control group. While the MPI obtained by PW Doppler was not different from the control group, the MPI calculated by PW-TDI was significantly high in the patient group. They indicated that the significant PR causes the low calculation of MPI by prolongation of the RV ET via PW Doppler, and therefore produces a false-normal value. They found longer ICT and IRT and shorter ET in the operated TOF group via PW-TDI method, and therefore higher MPI. In our study, ICT, IRT and ET were also found to be longer than in the control group; however, the prolongation of ICT and IRT was more evident. Therefore, the RV MPI was found to be higher than in the control group. Our study showed a positive correlation between MPI and RV systolic and diastolic volumes and also supported the view that RV dilatation and the increase of the volume negatively affect the ventricular functions. Similarly, it was shown that as the postoperative follow-up period extends, the MPI rises and also the progressiveness of the RV dysfunction was supported. While there are some studies in the literature[27] that reported a positive correlation between the increased

LV MPI and the dysfunctional capacity, no study was found comparing the RV MPI and the functional capacity of patients. The patient group, with its good functional capacity despite higher MPI, points to the view that the MPI is very important in monitoring the prognosis, since it facilitates diagnosis of ventricular dysfunction before clinical indications.

The contribution of PR in the development of RV dysfunction is known. Through the increasing use of TAP, the frequency of PR cases has also increased. In the operated TOF patients with TAP, the incidence of severe PR was reported as around 30% during 22 years of follow-up[28]. Since the follow-up period was short in our study, severe PR was detected in just one patient, but PR among patients with TAP was found to be higher, supporting this view. Moreover, in the patients with TAP and increased PR degree, the RV MPI was higher and the negative effects of TAP and PR on ventricular dysfunction were shown. It is a cause for future concern that, within an average of five years of follow-up, half of the patients had moderate PR.

In our study, no relationship was shown between either the RV or LV EF and MPI obtained via Simpson method. While the MPI is used to evaluate both systolic and diastolic functions, the Simpson method is only used to evaluate systolic functions, and therefore it would not be appropriate to compare these methods. Studies are needed to compare radionuclide ventriculography or MRI, both of which are shown to be reliable in RV functions, with MPI.

While there were more accurate results on the RV dysfunctions in patients after TOF repair, previous studies obtained differing results for LV dysfunctions. Generally, as the follow-up period extends, LV functions worsen. In a study conducted by radionuclide ventriculography, while the LV EF was 0.68 at 1.2 years of follow-up, it decreased to 0.60 after 9 years in the same patients[29]. In our study, the LV EF data obtained by the modified Simpson method were found to be lower than in the control group and found below 0.55 in 14 of the patients. In our study, while no significant difference was found in the ratio of EF obtained by the modified Simpson method, the LV MPI was higher in the patient group. ICT and IRT were longer in the patient group, but ET was the same as the control group; therefore, the LV MPI calculated using these parameters was higher in the patient group. Abd El Rahman et al.[3] showed that the LV MPI was higher in 23.5% of TOF patients and indicated that this was caused by the prolongation of ICT, which is supported by the findings in our study. IRT was also found to be longer in our study. Cheung and Norozi[30,31] found higher LV and RV MPI and elevated brain natriuretic peptide. While hypoxemia and myocardial fibrosis were the reasons for the LV global dysfunction, especially for patients with PR, bulging of the interventricular septum into the LV chamber affects the LV diastolic fill. In our study, a positive relationship was found between the LV MPI and RV EDV - supporting the view that the RV volume affects the LV functions. However, the effect of PR on the RV volume, and accordingly, on the LV functions, was supported by the significant relationship between the MPI and the degree of PR. The effects of both ventricles on each other were shown by the positive correlations between the RV and the LV MPI.

After total corrective surgeries, the exercise capacity of the patients is generally excellent. However, after intensive and heavy exercise, significant cardiopulmonary disorders were detected in the patients. Carvalho et al.[32] indicated a significant negative correlation between the degree of PR and exercise duration and the maximum heart rate. The results from 87 studies and more than 3000 patients showed that the consumption of oxygen, working capacity, maximum heart rate reached, and exercise duration all decreased. These findings were more prominent in patients who underwent surgery at older ages and had a longer follow-up[33]. In our study, the exercise duration of the patient group was shorter than in the control group. While no relationship was found between the RV MPI and the exercise duration, a negative correlation was indicated with the LV MPI, leading to the view that the LV functions have an important role in reducing exercise duration among postoperative patients.

Study Limitations

When evaluating our findings, it should be considered that the postoperative follow-up period was not long, with no patient having a follow-up period longer than two decades. In order to evaluate the relationship between MPI and the clinical findings of the patients, broader studies with longer follow-up and patients with the same disease but different clinical findings are required. Moreover, in our study, PW-TDI MPI was compared with standard echocardiographic methods. However, it is known that in patients with TOF, these methods are not very dependable for the RV. Therefore, further studies are required, comparing MPI to radionuclide ventriculography or MRI, both of which are demonstrated to be reliable in RV functions.

In conclusion, although the clinical conditions of the patients after TOF repair were good, some disorders were observed in both echocardiographic exam and exercise test in the mid-term (average 5 years) of the follow-up period. By using MPI to evaluate the RV and LV functions in the follow-up period, early precautions can be taken in the management of these patients before they become clinically symptomatic.

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