Original Article

# Right Ventricular Myocardial Tissue Velocities, Myocardial Performance Index, and Tricuspid Annular Plane Systolic Excursion in Totally Corrected Tetralogy of Fallot Patients

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## Abstract

***Background:*** *Longer survival after the total repair of the Tetralogy of Fallot increases the importance of late complications such as right ventricular dysfunction. This is a prospective study of the right ventricular function in totally corrected Tetralogy of Fallot patients versus healthy children.*

***Methods:*** *Thirty-two healthy children were prospectively compared with 30 totally corrected Tetralogy of Fallot patients. Right ventricular myocardial tissue velocities, right ventricular myocardial performance index, and tricuspid annular plane systolic excursion were investigated as well as the presence and severity of pulmonary regurgitation.*

***Results:*** *The two groups were age-and sex-matched. Mean systolic peak velocity (Sa) and tricuspid annular plane systolic excursion were significantly decreased, while myocardial performance index and early to late diastolic velocity (Ea/Aa) were significantly increased in the Tetralogy of Fallot patients. Early diastolic velocity (Ea) showed no significant difference between the two groups. Sa correlated significantly with tricuspid annular plane systolic excursion in both the normal children and totally corrected Tetralogy of Fallot patients. Myocardial performance index was significantly higher in the patients with moderate to severe pulmonary regurgitation than in those with mild regurgitation. However, there was no significant correlation between this index and right ventricular myocardial tissue velocities.*

***Conclusion:*** *In this study, systolic right ventricular function indices (Sa and tricuspid annular plane systolic excursion) were impaired in the totally corrected Tetralogy of Fallot patients. Myocardial performance index was affected by the severity of pulmonary regurgitation.*

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## Introduction

Although excellent outcomes have been achieved long after the total correction of the Tetralogy of Fallot (TOF) in the developed countries, right ventricular (RV) dysfunction may still cause mortality and morbidity.[1, 2] Pulmonary regurgitation (PR) has a detrimental effect on the RV diastolic function.[3] Late systolic RV dysfunction has been reported after the correction of the TOF in the developed countries.[4] The long-term survival after the TOF repair in the developing countries is unknown;[5, 6] we, therefore, sought to focus on the earlier RV function in these patients. We used the right ventricular myocardial performance index (RVMPI or Tei index), tricuspid annular plane systolic excursion (TAPSE), and myocardial tissue velocities for the evaluation of the RV systolic and diastolic functions in totally corrected TOF patients.[7]

## Methods

Thirty consecutive totally corrected TOF patients, who referred to our Outpatient Clinic between July 2008 and July 2009, were enrolled in the study and written informed consent was obtained from all of them. The study population underwent surgery using valved trans-annular patches, non-valved trans-annular patches, or sub-annular patches at a mean age of 3.6 ± 3.2 years. Thirty-two normal healthy children with innocent murmur were selected as the control group.

The inclusion criteria for this study included classic TOF with pulmonary stenosis. The exclusion criteria were other variants of the TOF (pulmonary atresia with ventricular septal defect [VSD], absent pulmonary valve, and double-outlet RV) and the presence of a significant residual abnormality (VSD, valvular or peripheral pulmonary stenosis, or tricuspid regurgitation) other than PR.

Echocardiography was performed using a single echocardiographic scanner (MicroMaxx Ultrasound System, Sonosite Inc., USA). RVMPI was measured using continuous pulse wave Doppler of the pulmonary and tricuspid valves. The formula a-b/b was used, where a was the time interval between cessation and onset of tricuspid inflow and b was pulmonary ejection time.[7]

The systolic displacement of the lateral portion of the tricuspid annular plan (TAPSE) was measured on the M-mode tracing under a two-dimensional echocardiogram in the four-chamber view.[8]

The averages of the RV systolic (Sa), early diastolic (Ea), and late diastolic velocities (Aa) in three cardiac cycles were measured using tissue Doppler echocardiography.[4] Three-millimeter Doppler sample volume was applied parallel to the RV free wall at the tricuspid valvular level to avoid sampling the right-heart cavities due to normal cardiac movement.

Severity of PR was assessed by color and continues Doppler studies in the parasternal short-axis view. Duration of the PR flow to total diastolic time (PR index and PRi) was measured. PRi ≥ 70% was defined as mild PR, while the lower values were defined as moderate to severe PR.[9, 10] The severity of PR was also assessed on the color Doppler imaging. The presence of persistent retrograde color flow from the distal main pulmonary artery or branches that extend into the RV was defined as moderate to severe PR.[3] The study was approved by the local Ethics Committee and it was conducted in accordance with good clinical practice and the Declaration of Helsinki.

For the statistical analyses, the statistical software SPSS version 13.0 for Windows (SPSS Inc., Chicago, IL) was used. An independent samples t-test was performed to compare the RV function indices between the normal children and TOF patients. A bivariate correlation was performed using the Pearson correlation coefficient between the RV function indices. Statistical significance was inferred at a p value $< 0.05$.

## Results

The 32 normal healthy children (17 males and 15 females at a mean age of 5.6 ± 3.8 years) and the 30 totally corrected TOF patients (17 males and 13 females at a mean age of 6.4 ± 4.1 years) were age- and sex-matched. PR severity was evaluated in all of the totally corrected TOF patients, of whom 15 had valved trans-annular, 8 non-valved trans-annular, and 7 sub-annular patches.

There were statistically significant differences in RVMPI, TAPSE, and myocardial tissue velocities (Sa, Aa, and Ea/Aa) between the healthy children and totally corrected TOF patients. There was no significant difference in Ea (Table 1).

Table 1. Indices of the RV function in the totally corrected TOF patients and normal healthy children*

| Variable | TOF group | Normal group | P value |
|---|---|---|---|
| RVMPI | 0.3±0.1 | 0.2±0.1 | 0.001 |
| TAPSE (mm) | 13.6±2.9 | 16.3±3.3 | 0.001 |
| Sa (cm/s) | 8.6±8.9 | 11.4±2.2 | < 0.001 |
| Ea (cm/s) | 10.9±3.3 | 11.9±2.1 | > 0.05 |
| Aa (cm/s) | 5.9±1.8 | 8.2±2.1 | < 0.001 |
| Ea/Aa | 2.0±0.8 | 1.5±0.4 | 0.015 |

*Data are presented as mean±SD

RV, Right ventricle; TOF, Tetralogy of Fallot; RVMPI, Right ventricular myocardial performance index; TAPSE, Tricuspid annular plain systolic excursion; Sa, RV systolic velocity; Ea, Early diastolic velocity; Aa, Late diastolic velocity

The Pearson analysis showed a strong correlation between

TAPSE and Sa both in the control (r = 0.755, p value < 0.001) and patient (r = 0.662, p value = 0.002) groups. There was a significant inverse correlation between Sa and RVMPI (p value = 0.001) in the control group but not in the patient group (p value = 0.054). There was no significant correlation between RVMPI and Ea/Aa in either group.

PRi was measured in all the totally corrected TOF patients, of whom 13 had a value ≥ 70% (mild PR) and 17 had a value < 70% (moderate to severe PR). PRi < 50% was found in 2 patients. There was a significant correlation between RVMPI and PRi (p value < 0.001) in the patient group. The RVMPI in patients with PRi < 70% was 0.42 ± 0.13, which differed significantly from the RVMPI (0.24 ± 0.1) in the patients with PRi ≥ 70% (p value < 0.05). In the 2 patients with PRi < 50%, RVMPI was 0.62 and 0.47, respectively. There was no significant difference in the Ea/Aa ratio between the patients who had PRi ≥ 70% and those who had PRi < 70% (p value = 0.38). The Ea/Aa ratio was insignificantly higher in PRi < 70% (2.1 ± 9.4 vs. 1.85 ± 7.4; p value = 0.405). In the 2 patients who had PRi < 50%, the Ea/Aa ratio was 4.57/1 and 2.92/1, respectively (restrictive pattern).

In the color flow Doppler assessment of PR, 11 patients had mild PR and 19 had moderate to severe PR. There was a significant correlation between PR severity in the retrograde color flow mapping and RVMPI (p value = 0.023), but there was no correlation between PR severity and Ea/Aa ratio (p value = 0.38).

## *Discussion*

Advances in cardiac surgery and postoperative management in the developed countries have contributed to the excellent long-term outcome of the totally corrected TOF patients;[1] nevertheless, the long-term outcome of the corrected TOF surgery in developing countries is unknown.[5, 6] In the developed countries, PR and RV diastolic dysfunction is the most important outcome factor following the TOF repair.[2, 3] There are reports of the usage of pulmonary valve sparing surgery to decrease the severity of PR in the TOF patients.[11, 12] Intra- and postoperative management problems, delay in corrective surgery, and palliative surgery (aorto-pulmonary shunts) are probably additional contributory factors to the poor long-term outcome in developing countries.[5, 6] At follow-ups of the repaired TOF patients, simple and fast evaluation of the systolic and diastolic RV functions is of great importance.

In our study, the RV systolic and diastolic function indices were clearly impaired in the TOF patients in comparison with the normal children at mid-term follow-ups (Table 1). A few studies have focused on the RV function at mid-term follow-up after the TOF repair. Pilla et al. evaluated the presence of mid-term RV dysfunction and health-related quality of life after the TOF repair in Brazil.[13] In their investigation, 35 patients at a median age of 6.1 years and 4.9 years of follow-up after surgery were compared with 36 sex- and age-matched healthy controls and RVMPI (0.34 vs. 0.2) demonstrated RV dysfunction in the patients compared with the controls. In adult patients late after the repair of the TOF, D'Andrea et al. detected a correlation between myocardial performance assessed at rest via tissue Doppler (TD) and cardiac performance during physical effort in adult patients (21.4 ± 3.8 years).[4] In their study, TD analysis showed lower Sa, Ea, Ea/Aa ratios in the corrected TOF patients compared to the normal group. In contrast to our study, the corrected TOF patients of their study had no significant PR, the mean age of the TOF patients was higher than that in our study (21.4 ± 3.8 vs. 6.3 ± 3.3 years), and the mean age of the corrected TOF patients was lower than that in our study (1.4 ± 0.5 vs. 3.6 ± 3.2 years).[4] In the Puranik et al. study, Sa and Ea were significantly lower in asymptomatic corrected adult TOF patients compared with their normal group.[14] Similar to our study, there was significant PR but the age at corrective surgery was higher (6.6 vs. 3.6 years). Although the increased Ea/Aa ratio in our study, in contrast to the D'Andrea's, may suggest the role of combined prolonged cyanosis and post-correction PR, a comparison with the Puranik study emphasizes the importance of other factors in the restrictive diastolic RV dysfunction in our patients.[4, 14] On the other hand, while our study demonstrates combined systolic dysfunction (decrease in both Sa and TAPSE) and restrictive RV dysfunction (increase in Ea/Aa ratio), the two other studies[4, 14] showed mild systolic dysfunction (decrease in Sa) associated with a significant decrease in Ea/Aa in adult corrected TOF patients. Frigola et al. reported that PR was an important factor of RV contractile dysfunction after the TOF repair.[15] These observations may suggest that the systolic and restrictive diastolic RV dysfunctions in our study probably originated through others mechanisms and they were present since the early postoperative period. In a study by Cullen et al,[16] patients with early restrictive physiology after the TOF repair had a clinical picture of low cardiac output and slow postoperative recovery but a study by Gatzoulis et al. suggested that late restrictive physiology predicted a superior exercise performance.[17] Further studies are clearly warranted about how the RV systolic and diastolic functions correlate with intra- and early postoperative management and PR. In addition to significant PR and prolonged preoperative cyanosis, intra- or early postoperative management may have been affected by systolic and restrictive diastolic RV functions in our study.[6] Although RVMPI was significantly correlated with PR severity (retrograde color flow and PRi), there was no significant correlation between RVMPI and Ea/Aa ratio. In our 2 patients with severe PR (PRi < 50%), the Ea/Aa ratio was significantly elevated. As RVMPI was not correlated with systolic and diastolic function indices (Sa, TAPSE, Ea, and Ea/Aa) but was allied to PR severity, RVMPI may have been affected more by PR severity than

by the RV function in the totally corrected TOF patients with restrictive physiology. In accordance with our study, Abd El Rahman et al. suggested that MPI was affected by the severity of PR in the presence of RV diastolic dysfunction.[18] Yasuoka et al. showed that MPI obtained by pulsed wave Doppler was not different in patients with the TOF repair compared with normal children but RVMPI measured by tissue Doppler was significantly higher in patients with the TOF than in normal children.[19]

The current study had some limitations. The sample size was inadequate to compare the totally corrected TOF subgroups. Furthermore, half of the corrected TOF patients underwent valved trans-annular patch repair, which is a new technique for right ventricular outflow tract reconstruction.

## Conclusion

RVMPI was significantly correlated with PR severity without the presence of a significant correlation between RVMPI (obtained by pulsed wave Doppler) and the RV function indices obtained by tissue Doppler imaging (EA, Aa, Ea/Aa, and Sa). We suggest that these indices, RVMPI by tissue Doppler and PRi, be measured basically at postoperative and follow-up evaluations. In addition, as TAPSE was significantly decreased in the totally corrected TOF patients and there was a significant correlation between TAPSE and Sa, we suggest that TAPSE be also measured as the global RV systolic function index.

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