

## Original Article

# Clinical value of Tei index in pediatric patients with repaired tetralogy of Fallot

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**Abstract:** Purpose: Tetralogy of Fallot is a congenital heart disease characterized by underdevelopment of the right ventricular infundibulum. Present study aimed to explore the clinic value of Tei index in assessing right ventricular function of pediatric patients with repaired Tetralogy of Fallot. Methods: A total of 45 pediatric patients with repaired Tetralogy of Fallot were recruited and classified into: group A (Tei index  $<0.5$ ;  $n=13$ , aging 2-12 years), group B ( $0.5 < \text{Tei index} < 0.7$ ;  $n=19$ , aging 1-14 years), and group C (Tei index  $>0.7$ ;  $n=13$ , aging 4-14 years). The right ventricular Tei index value was related to the clinical characteristics of Tetralogy of Fallot repair patients. Results: Right ventricular Tei index was positively correlated with ventilation time, drainage volumes, and negatively with drug assistance and Intensive Care Unit (ICU) stay, although time for drug assistance and ICU stay were not statically different between group B and group C. There was no significant difference in left ventricular ejection fraction. Conclusion: Tei index is a sensitive indicator of right ventricular dysfunction, and has important clinical value to better our understanding of right ventricular function after tetralogy of Fallot repair.

**Keywords:** Tei index, tetralogy of Fallot, right ventricle function, intensive care unit (ICU)

## Introduction

Tetralogy of Fallot is a congenital heart disease (CHD) characterized by underdevelopment of the right ventricular infundibulum due to the pulmonary stenosis and the ventricular septal defect. It occurs in about four per 10,000 live births, and accounts for up to one-tenth of all congenital cardiac lesions [1]. Patients with repaired Tetralogy of Fallot are at risk for progressive right ventricular dilatation and dysfunction [2, 3], associated with clinically important decreases in their life quality, and hence, the assessment of right ventricular function is of major importance for clinical diagnosis and management in these patients.

To access the cardiac metrics such as cardiac chamber dimensions, volumes, and performances in clinical practices, a number of non-invasive imaging techniques have been employed such as echocardiography and nuclear cardiograph, and cardiac magnetic resonance. With recent advances in Doppler tissue echocardiography, Tei index, also known as myocardial performance index, has been suggested to be a simple, reproducible method for measuring regional and global right ventricular

function. As a noninvasive Doppler measurement of ventricular function, Tei index has been reported to correlate well with other invasive and noninvasive measures [4, 5]. Because this index is essentially a time ratio, it is therefore independent of ventricular geometry, heart rate, blood pressure, and may be particularly useful in assessment of the global right ventricular function [6], especially in children with complex right ventricular shape. It is therefore important to explore the clinic value of Tei index in assessing right ventricular function of pediatric patients with repaired Tetralogy of Fallot. However, knowledge of the impact of differences in Tei index on clinical characteristics of Tetralogy of Fallot repair patients is limiting, its clinical functional status remains to be clarified. The present study aimed to explore the clinical value of right ventricular Tei index by investigating its relationships with clinical characteristics of postoperative Tetralogy of Fallot patients.

## Patients and methods

### Study population

This study was approved by the local ethical review board of our institution, and written

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**Table 1.** Demographic data of tetralogy of Fallot repair patients with different level of Tei index

	Tei-index value	Gender (male, %)	Age (yr) (range)
Group A	<0.5	9/69.2%	5.92±2.78 (2-12)
Group B	0.5</>0.7	15/78.9%	7.26±3.68 (1-14)
Group C	>0.7	10/76.9%	7.46±2.85 (4-14)

informed consent was obtained from the subjects and parents of minors. Individuals for this study were recruited from the department of cardiovascular surgery, First Hospital of Lanzhou University. A total of 45 pediatric patients (34 males, 11 females), with surgically corrected Tetralogy of Fallot between October 2008 and June 2012, were eligible for this study. All patients were asymptomatic and selected based on an exclusion criteria without renal insufficiency, severe arrhythmia, pulmonary or mitral regurgitation, residual ventricular septal defect or ventricular extrasystoles, and had an adequate transthoracic window for echocardiographic examination. They were classified into three groups on the basis of their postoperative Tei values: group A (Tei index <0.5), group B (0.5< Tei index <0.7), group C (Tei index >0.7). The descriptive data of our patient cohort were shown in **Table 1**. Patients with any additional underlying disease that could interfere with the clinical evaluation were excluded from the study. At surgical repair, all had been treated with a transannular patch for Tetralogy of Fallot.

### *Echocardiography*

All pediatric patients underwent echocardiographic examination for the assessment of cardiac function within a week post-operation. An HP5500 ultrasound system (Philips) was used, and transthoracic echocardiography was performed with a 2 to 4 MHz 4× matrix probe. Echocardiograms for all patients performed under identical clinical situations. Patients were examined in a horizontal or left lateral decubitus position, and their electrocardiograms were simultaneously recorded for subsequent off-line analysis. Two-dimensional image of the standard apical 4-chamber sections was clearly displayed in the first place, and then tissue Doppler mode was employed with the scanning velocity range set between 100-150

mmPs. A sample volume of 3.5 mm was placed on the free wall of the right ventricle, and a simultaneous dynamic spectrum was recorded. For each circulatory situation, the duration was measured from the peak of the R wave of the electrocardiogram to the onset of the late diastolic A-wave of the next cardiac cycle. Systolic S wave duration Ds was measured as the interval from the onset to the end of the right ventricular outflow profile. The sum of isovolumetric contraction time and isovolumetric relaxation time was measured as the interval from the cessation to the onset of the tricuspid inflow. Tei index value was calculated as described previously [7]. All parameters were measured on 3 to 6 consecutive heart cycles and values from three consecutive cardiac cycles were averaged.

### *Statistical analysis*

All statistical analyses were performed with SPSS, version 11.5 (SPSS Inc., Chicago, IL, USA). Data were expressed as mean value ± standard deviation. Comparison between the groups was performed by unpaired t test. A *P*-value of <0.05 was considered statistically significant.

## **Results**

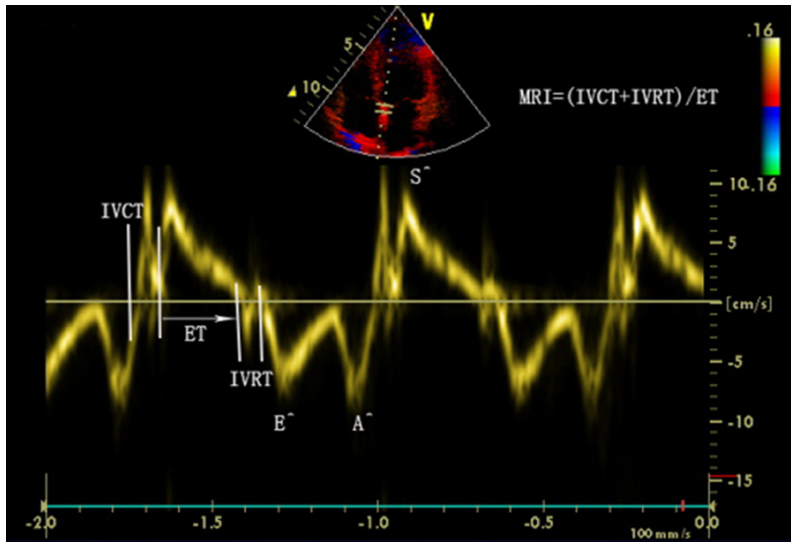
### *Background information*

All 45 pediatric patients had undergone Tetralogy of Fallot repair with a transannular patch, they were assigned to three groups according to their postoperative Tei index value. The age was ranged from 1 to 14 years as shown in **Table 1**. There were no significant differences among the patients in three study groups with respect to age and sex distributions, and the age at repair was also not statistically different among the three groups of patients (*P*>0.05). All the patients denied any other obvious complications.

### *Postoperative Doppler data*

Echocardiogram of the pediatric patient was shown in **Figure 1**, and the way how the Tei index value obtained was clearly described. **Table 2** summarizes the postoperative Doppler time intervals and Tei-index value for 3 study groups. Left ventricular ejection fraction did not differ significantly among the groups, and were

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**Figure 1.** Echocardiogram of the pediatric patient and the way how the Tei index value was obtained.

within normal limits in all the patients ( $P>0.05$ ). However, There was a statistical differences in the Tei-index values among the 3 study groups ( $P<0.05$ ). Both right ventricular isovolumetric contraction time and isovolumetric relaxation time were prolonged and right ventricular Ds shortened in Group C patients, when compared with patients in Group A and B. Right ventricular isovolumetric contraction time and isovolumetric relaxation time for group B patients were also prolonged, while right ventricular systolic S wave duration Ds was shortened to some extent compared with that of the Group A.

### *Clinical characteristics*

The clinical characteristics of the three study groups were presented in **Table 3**. Clinical observation showed that postoperative ventilation time and drainage volumes were differ significantly among the three groups, with shortest ventilation time and lest drainage volume demonstrated in Group A patients. Time for drug assistance and ICU stay were not statically different between the group B and group C patients. However, in group A patients with the lowest Tei-index value, both the time for drug assistance and ICU stay were slightly but significantly increased compared with that of both group B and group C patients ( $P<0.05$ ).

### **Discussion**

Tetralogy of Fallot is the most common congenital cardiac defect, occurring in 4 out of every

10,000 live births. After the pioneering experience of Castaneda and colleagues [8], primary repair of this lesion was recommended in early infancy to minimize right ventricular hypertrophy. Surgical repair of Tetralogy of Fallot in infancy and childhood has been reported to be effective in terms of clinical health assessment and exercise capacity. However, the right ventricle was reported to be vulnerable to functional compromise in patients after surgical repair of Tetralogy of Fallot [9-11], Right ventricular dysfunction was also well documented in post-operation Tetralogy of

Fallot patients [12, 13], and was suggested to be directly associated with the clinically important decreases in their life quality and survival rate. Therefore, definitive assessment of right ventricular function may play a significant important role after surgical repair of patients with Tetralogy of Fallot.

In the clinical management of patients with CHD, the evaluation of the global right ventricular function is of major importance [14]. Magnetic resonance imaging and computed tomography proved to be useful for the assessment of right ventricular function [15]. However, the techniques are not appropriate for small children because they require deep sedation [16]. Echocardiography, described as a simple, safe, reproducible and noninvasive technique for determining cardiac systolic and diastolic function, has gained general acceptance from patients and clinicians. Although there are many parameters that can be used for the quantitative assessment of ventricular function, most pointed to the left ventricular physiology. No ideal parameter has been established for the quantitative assessment of right ventricular function, given the complex geometry of the right ventricle with its extensive trabeculation.

Pathological examination of right ventricle showed complicated pathological features, with both the systolic dysfunction and diastolic dysfunction involved and correlated. Recently,

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**Table 2.** Comparison of Tei index value among the three study groups

	n	Tei-index value	IVCT/ms	IVRT/ms	Ds/ms	LVEF
Group A	13	0.44±4.68	60.60±6.91	64.14±9.48	279.52±10.43	60.15±9.40
Group B	19	0.59±5.83*	69.08±7.10	79.54±14.15	251.44±28.57	63.63±9.74
Group C	13	0.79±5.93#	69.67±11.05	80.19±16.94	223.22±15.50	61.08±6.34

IVCT: Isovolumetric contraction time; IVRT: Isovolumetric relaxation time; Ds: Systolic S wave duration; LVEF: left ventricular ejection fraction; \*P<0.05 vs. the Group A; #P<0.05 vs. the Group B.

**Table 3.** Comparison of the clinic index among the three study groups

	Ventilation time/h	ICU/h	Drug assistance/h	Drainage/ml
Group A	16.92±9.94	21.00±5.85	30.85±8.15	209.46±98.70
Group B	24.53±6.75*	18.05±2.17*	26.21±2.74*	320.74±124.20*
Group C	30.92±9.11#	18.05±0.00*	26.00±0.00*	464.23±215.64#
F value	8.944	3.458	4.865	9.364
P value	0.001	0.041	0.013	0.000

ICU: Intensive care unit; \*P<0.05 vs. the Group A; #P<0.05 vs. the Group B.

an easily measured Doppler index, Tei index combining systolic and diastolic time intervals has been proposed. Tei index is a function of both systolic and diastolic time intervals and appears to be sensitive to abnormalities of cardiac systolic and diastolic function [17]. It has been suggested to be the most discriminatory index, with good reproducibility [18]. Mahapatra proposed that this index represented a sensitive quantitative method for right ventricular function evaluation, with wide clinical application [19, 20]. Since Tei index is essentially a time ratio [21, 22], it is therefore independent of ventricular geometry, heart rate, preload and may be particularly useful in assessment of the global right ventricular function under various patho-physiological states [4, 23]. The clinical implications of an elevated right ventricular Tei index in Tetralogy of Fallot repaired patients, however, have not been assessed systematically.

In this study, the clinical presentations of an elevated right ventricular Tei index were recorded and comparatively analyzed in a cohort of pediatric Tetralogy of Fallot repair patients, with significant difference in right ventricular Tei-index values demonstrated in the 3 study groups (Group A: 0.44±4.68, Group B: 0.59±5.83, Group C: 0.79±5.93; P<0.05). While there was no statistical differences in left ventricular ejection fraction in the overall process (Group A: 60.15±9.40, Group B:

63.63±9.74, Group C: 61.08±6.34; P>0.05). It indicated that abnormality of right ventricular Tei index value can be detected beforehand in the Tetralogy of Fallot repaired children, even before the presentation of any cardiac dysfunctions. In addition, among the postoperative clinical characteristics, ventilation time and drainage volumes were significantly different among the three groups. However, time for drug

assistance and ICU stay were not statically different between the group B and group C patients, although they were significantly different from that of group A patients (P<0.05). Therefore, Tei index may provide a good guideline for respirator auxiliary time and drainage volumes in Tetralogy of Fallot repair patients. The lack of significant impact of Tei index on drug assistance and ICU stay was perhaps understandable considering the small sample used in this study.

Our preliminary data suggest that Tei index is potentially a simple, readily available, reproducible and more sensitive indicator of right ventricular dysfunction, and has important clinical value in better our understanding of the right ventricular function after surgical correction of Tetralogy of Fallot, corroborating the results of previous studies [20, 24]. However, this index also has some limitations, it occasionally lacks sensitivity and has somewhat low negative predictive power due to a significant false-negative rate [25]. Furthermore, it was also suggested that Tei index may be good for measuring regional function of right ventricular, but lack accuracy in global functional assessment due to the dysfunction of the right ventricular outflow tract [26]. Only through fully understanding correlation of its potential characteristics with clinical presentations, the clinical value of this index can be fully developed.

The relatively small sample size was a limitation of this study, and further investigation should focus on closer analyze the clinical value of Tei index in the large majority of patients. Besides, the criteria by which patients were assigned to particular groups were arbitrarily defined according to our Tei value distribution. However, Tei values obtained in Tetralogy of Fallot repair patients have varied among studies. In adult patients after surgical correction of Tetralogy of Fallot, a right ventricular Tei index of  $0.21 \pm 0.10$  has been reported to represent normal right ventricular function [27]. Similarly, in the pediatric counterpart, a right ventricular Tei index of  $0.29 \pm 0.17$  was found despite of an extreme low value of right ventricular Tei index ( $0.16 \pm 0.15$ ) detected in the normal control [28]. While the right ventricular Tei index of  $0.52 \pm 0.08$  (ranged from 0.28 to 0.69) was reported to represent normal right ventricular function after surgical repair of patients with Tetralogy of Fallot [26], and in the study of Jaroslav Meluzin et al, a right ventricular Tei index of more than 1.00 was also reported [20]. Therefore, the Tei index value measured in our study seem to be rational and accurate when used in exploration of its clinic value in patients with Tetralogy of Fallot postoperatively.

In conclusion, the findings of the present study suggest that right ventricular Tei index is potentially a simple, readily available, reproducible and more sensitive indicator of right ventricular dysfunction. The increased right ventricular Tei index, found in some of the pediatric patients after Tetralogy of Fallot repair, was statistically correlated with prolonged postoperative ventilation time and drainage volumes, while it was less significantly correlated with shortened duration of drug assistance and ICU stay. Serial monitoring of the right ventricular Tei index in the follow-up process of these patients may prove to be a useful adjunct in decision of interventions to preserve their right ventricular function and improve their life quality.

### Disclosure of conflict of interest

None.

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### References

- [1] Oswal N, Christov G, Sridharan S, Khambadkone S, Bull C and Sullivan I. Aberrant subclavian artery origin in tetralogy of Fallot with pulmonary stenosis is associated with chromosomal or genetic abnormality. *Cardiol Young* 2014; 24: 478-84.
- [2] Bouzas B, Kilner PJ and Gatzoulis MA. Pulmonary regurgitation: not a benign lesion. *Eur Heart J* 2005; 26: 433-439.
- [3] Geva T, Sandweiss BM, Gauvreau K, Lock JE and Powell AJ. Factors associated with impaired clinical status in long-term survivors of tetralogy of Fallot repair evaluated by magnetic resonance imaging. *J Am Coll Cardiol* 2004; 43: 1068-1074.
- [4] Grignola JC, Ginés F and Guzzo D. Comparison of the Tei index with invasive measurements of right ventricular function. *Int J Cardiol* 2006; 113: 25-33.
- [5] Su HM, Lin TH, Voon WC, Lee KT, Chu CS, Yen HW, Lai WT and Sheu SH. Correlation of Tei index obtained from tissue Doppler echocardiography with invasive measurements of left ventricular performance. *Echocardiography* 2007; 24: 252-257.
- [6] LaCorte JC, Cabreriza SE, Rabkin DG, Printz BF, Coku L, Weinberg A, Gersony WM and Spotnitz HM. Correlation of the Tei index with invasive measurements of ventricular function in a porcine model. *J Am Soc Echocardiogr* 2003; 16: 442-447.
- [7] Özdemir K, Altunkeser BB and Gök H. Does the myocardial performance index affect pulmonary artery pressure in patients with mitral stenosis? A tissue Doppler imaging study. *Echocardiography* 2003; 20: 249-256.
- [8] Castaneda A, Freed M, Williams R and Norwood W. Repair of tetralogy of Fallot in infancy. Early and late results. *J Thorac Cardiovas Surg* 1977; 74: 372.
- [9] D'Andrea A, Caso P, Sarubbi B, Russo M, Ascione L, Scherillo M, Cobrufo M and Calabrò R. Right ventricular myocardial dysfunction in adult patients late after repair of tetralogy of fallot. *Int J Cardiol* 2004; 94: 213-220.
- [10] Davlouros PA, Kilner PJ, Hornung TS, Li W, Francis JM, Moon JC, Smith GC, Tat T, Pennell DJ and Gatzoulis MA. Right ventricular function in adults with repaired tetralogy of Fallot assessed with cardiovascular magnetic resonance imaging: detrimental role of right ventricular outflow aneurysms or akinesia and adverse right-to-left ventricular interaction. *J Am Coll Cardiol* 2002; 40: 2044-2052.
- [11] Helbing WA, Niezen RA, Le Cessie S, Van Der Geest RJ, Ottenkamp J and De Roos A. Right ventricular diastolic function in children with pulmonary regurgitation after repair of tetralo-

## Tei index in TOF repaired pediatric patients

- gy of Fallot: volumetric evaluation by magnetic resonance velocity mapping. *J Am Coll Cardiol* 1996; 28: 1827-1835.
- [12] Gatzoulis MA, Elliott JT, Guru V, Siu SC, Warsi MA, Webb GD, Williams WG, Liu P and McLaughlin PR. Right and left ventricular systolic function late after repair of tetralogy of Fallot. *Am J Cardiol* 2000; 86: 1352-1357.
- [13] Uebing A, Fischer G, Bethge M, Scheewe J, Schmiel F, Stieh J, Brossmann J and Kramer H. Influence of the pulmonary annulus diameter on pulmonary regurgitation and right ventricular pressure load after repair of tetralogy of Fallot. *Heart* 2002; 88: 510-514.
- [14] Nishimura R, Pieroni D, Bierman F, Colan S, Kaufman S, Sanders S, Seward J, JAMIL TAJIK A, Wiggins J and Zahka K. Second natural history study of congenital heart defects: pulmonary stenosis: echocardiography. Monograph-American Heart Association 1993; 87: 173-179.
- [15] Helbing WA, Rebergen SA, Maliepaard C, Hansen B, Ottenkamp J, Reiber JH and de Roos A. Quantification of right ventricular function with magnetic resonance imaging in children with normal hearts and with congenital heart disease. *Am Heart J* 1995; 130: 828-837.
- [16] Ding J, Ma G, Huang Y, Zhang X, Zhu J, Yang R and Lu F. Usefulness of myocardial performance index for assessing right ventricular function after percutaneous closure of atrial septal defect. *Journal of Geriatric Cardiology* 2007; 4: 220-224.
- [17] Chuwa T and Rodeheffer RJ. New index of combined systolic and diastolic myocardial performance: a simple and reproducible measure of cardiac function—a study in normals and dilated Cardiomyopathy. *J Cardiol* 1995; 26: 7-366.
- [18] Ling LH, Tei C, McCully RB, Bailey KR, Seward JB and Pellikka PA. Analysis of systolic and diastolic time intervals during dobutamine-atropine stress echocardiography: diagnostic potential of the Doppler myocardial performance index. *J Am Soc Echocardiogr* 2001; 14: 978-986.
- [19] Blanchard DG, Malouf PJ, Gurudevan SV, Auger WR, Madani MM, Thistlethwaite P, Waltman TJ, Daniels LB, Raisinghani AB and DeMaria AN. Utility of right ventricular Tei index in the noninvasive evaluation of chronic thromboembolic pulmonary hypertension before and after pulmonary thromboendarterectomy. *JACC* 2009; 2: 143-149.
- [20] Meluzin J, Spinarová L, Hude P, Krejčí J, Kincl V, Panovský R and Dusek L. Prognostic importance of various echocardiographic right ventricular functional parameters in patients with symptomatic heart failure. *J Am Soc Echocardiogr* 2005; 18: 435-444.
- [21] Ishii M, Tsutsumi T, Himeno W, Eto G, Furui J, Hashino K, Sugahara Y, Muta H, Akagi T and Ando A. Sequential evaluation of left ventricular myocardial performance in children after anthracycline therapy. *Am J Cardiol* 2000; 86: 1279-1281.
- [22] Tei C, Dujardin KS, Hodge DO, Kyle RA, Jamil Tajik A and Seward JB. Doppler index combining systolic and diastolic myocardial performance: Clinical value in cardiac amyloidosis. *J Am Coll Cardiol* 1996; 28: 658-664.
- [23] Roberson DA and Cui W. Right ventricular Tei index in children: effect of method, age, body surface area, and heart rate. *J Am Soc Echocardiogr* 2007; 20: 764-770.
- [24] Leonard GT Jr, Fricker FJ, Pruett D, Harker K, Williams B and Schowengerdt KO Jr. Increased myocardial performance index correlates with biopsy-proven rejection in pediatric heart transplant recipients. *J Heart Lung Transplant* 2006; 25: 61-66.
- [25] Patel DR, Cui W, Gambetta K and Roberson DA. A comparison of Tei index versus systolic to diastolic ratio to detect left ventricular dysfunction in pediatric patients. *J Am Soc Echocardiogr* 2009; 22: 152-158.
- [26] Kutty S, Zhou J, Gauvreau K, Trincado C, Powell AJ and Geva T. Regional dysfunction of the right ventricular outflow tract reduces the accuracy of Doppler tissue imaging assessment of global right ventricular systolic function in patients with repaired tetralogy of Fallot. *J Am Soc Echocardiogr* 2011; 24: 637-643.
- [27] Schwerzmann M, Samman AM, Salehian O, Holm J, Provost Y, Webb GD, Therrien J, Siu SC and Silversides CK. Comparison of echocardiographic and cardiac magnetic resonance imaging for assessing right ventricular function in adults with repaired tetralogy of Fallot. *Am J Cardiol* 2007; 99: 1593-1597.
- [28] Cheung EW, Lam WW, Chiu CS, Chau AK, Cheung SC and Cheung YF. Plasma brain natriuretic peptide levels, right ventricular volume overload and exercise capacity in adolescents after surgical repair of tetralogy of Fallot. *Int J Cardiol* 2007; 121: 155-162.