ORIGINAL ARTICLE

Perioperative assessment of left ventricular function in patients with mitral valve stenosis undergoing mitral valve replacement: Utility of Tei index and ejection fraction

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ABSTRACT

Background & objectives: In the presence of mitral stenosis, LV conditions are modified with a trend to decrease preload and increase afterload. Under these hemodynamic conditions, the assessment of myocardial contractility by ejection phase measurements may be inappropriate, as these are well known to be influenced by acute changes in loading conditions. Tei index expressing global cardiac function has been reported as unchanged after mitral valve surgery. The hypothesis was tested where the Tei index could be useful in assessing the perioperative cardiac function in mitral stenosis patients undergoing mitral valve replacement.

Methodology: Transesophageal echocardiography was performed in 50 Mitral Stenosis patients before and after mitral valve replacement. Ejection fraction (calculated from LV end-diastolic and end-systolic areas obtained through the transgastric mid short-axis view) and Tei index (calculated from the mid-oesophageal four-chamber view and the deep transgastric long-axis view) was compared in these patients.

Results: In this study, the difference between pre-operative and post-operative Tei Index was statistically not significant while the difference between pre-operative and post-operative Ejection fraction was statistically significant.

Conclusion: Unlike ejection fraction, Tei index is not influenced by mitral valve replacement. Tei index is a better parameter to assess left ventricular function.

Keywords: Tei index; Ejection fraction; Cardiopulmonary bypass; Myocardial function; Monitoring; Echocardiography

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INTRODUCTION

Rheumatic mitral valve stenosis (MS) is one of the commonest valvular heart lesions in India and other developing countries.[1] Ejection Fraction[2] (EF) and Doppler estimation of transmitral flow are the commonly used Echocardiographic indices to assess perioperative LV systolic and diastolic functions respectively, in patients undergoing cardiac surgery. There are quite a few limitations to the use of these echocardiographic indices for the estimation of systolic and diastolic left ventricular (LV) function. The ejection fraction is subject to large errors when the shape of the heart changes. Age, arrhythmias, conduction disturbances, and acute changes in LV preload affect the Doppler signal of transmitral flow, thereby producing errors in estimation of diastolic function.[3] Tei Chuwa [3] (1995) introduced an index of myocardial performance (the Tei index) that evaluates the LV systolic and diastolic function in combination. Tei index is defined as the sum of isovolumic contraction time or mitral valve closure to aortic valve opening time and isovolumic relaxation time or aortic valve closure to mitral valve opening time divided by ejection time[3]. (Figure I) .The Tei index has proved to be a reliable method for the evaluation of LV systolic and diastolic performance, with clear advantages over older established indexes and prognostic value in various cardiac illnesses[4]. Besides, since

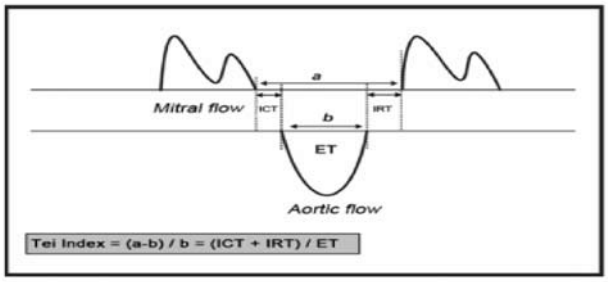

Figure 1: Calculation of Tei index
Measurement of Tei index. (A) The interval (a) represents the interval between the cessation and onset of mitral inflow (mid-oesophageal four-chamber view). This time corresponds to the sum of isovolumetric contraction, ejection time, and isovolumetric relaxation. (B) Ejection time (b) is measured from the pulsed-wave Doppler recordings of the left ventricular outflow signal (deep transgastric view). The Tei index is defined as the sum of the times of isovolumetric contraction and relaxation times (a–b) divided by the ejection time (b).[2]

systolic and diastolic dysfunctions frequently coexist, it is hypothetized that a combined measure of LV chamber performance may be more reflective of overall cardiac dysfunction than systolic and diastolic measures alone. Although Tei Index has been compared with Fractional Area Change (FAC) and Ejection Fraction in various clinical groups, the data in patients undergoing Mitral Valve Replacement (MVR) is missing. If proved useful, Tei Index can be an important indicator for perioperative inotropic support and postoperative functional status. Hence, the aim of this observational study was to test the utility of Tei Index and Ejection Fraction in assessing the perioperative cardiac function in patients with mitral valve stenosis undergoing mitral valve replacement.

METHODOLOGY

After the approval from institutional ethics committee the study was carried out on 50 Mitral Stenosis patients undergoing MVR. All consenting adults more than 18 years of age, with MS coming for MVR were included in the study. Patients having any contradiction for trans-esophageal echocardiography (TEE) and MS patients with other coexisting cardiac conditions like atrial septal defects, thrombus in left atrium, aortic valve pathology, presence of a supraventricular arrhythmia or coronary artery disease, coexisting valvular disease were excluded from the study. Transesophageal echocardiography was performed in these patients before and after mitral valve replacement. After induction of anaesthesia, the TEE probe was introduced into the esophagus. Before the patient went on to Cardio Pulmonary Bypass (CPB), transesophageal echocardiographic examinations were performed after sternotomy by experienced operators. This was repeated after weaning from cardiopulmonary bypass, but before starting any inotropic support. All the echocardiographic images were recorded during a period of brief apnea and under hemodynamic monitoring on an optical disk for offline measurements later. For each echocardiographic parameter, a mean of three retrospective offline measurements were obtained from consecutive beats. First, the mid-esophageal four-chamber view enabled the recording of the pulse wave Doppler of mitral inflow. The Doppler cursor was positioned at the tip of the mitral leaflets during diastole allowing the calculation of the interval between cessation and onset of mitral inflow. This interval corresponds to the sum of isovolumetric contraction time, ejection time, and isovolumetric relaxation time. Secondly, the deep transgastric long-axis view permitted recording of the pulsed-wave Doppler of the LV outflow signal and measurement of the ejection time. The Tei index is defined as the sum of isovolumetric contraction and relaxation times divided by the ejection time (Fig. I). Thirdly, LV end-diastolic and end-systolic areas were obtained through the transgastric mid short-axis view to calculate EF-FAC, defined as the difference between the end-diastolic and end-systolic areas of the LV, divided by the LV end diastolic area expressed as a percentage. The variables are expressed as mean (SD). Statistical analysis was performed using a paired student t-test.

RESULTS

The perioperative characteristics of the patients are summarized in Table 1. All our patients were having rheumatic etiology. During echocardiographic measurements, haemodynamic profile of patients was stable as shown in Table 2 and Table 3 shows Tei index. The mean Tei index preoperatively was 0.3212 with a SD of 0.0206 and the mean Tei index post operatively

Table 1: Perioperative characteristics of the patients

No.	Parameter	Value
1.	Age (years)	39.08 ± 4.25*
2.	Male/ Female	21/29
3.	Weight (kg)	57.58 ± 11.29*
4.	Height (cm)	160.02 ± 9.03*
5.	Etiology of MS: Rheumatic	100%
6.	**Preop Medications;**	
	Beta Blockers	15%
	Digoxin	10%
	Frusemide	17%
	ACE Inhibitors	5%
7.	**Intraoperative variables;**	
	Duration of cardiopulmonary bypass(minutes)	90 ± 22*
	Duration of aortic cross clamping (minutes)	65 ± 18*

*Mean ± SD

Table 2: Hemodynamic profile during echocardiography examination

	Hemodynamic parameters	Beginning (Mean ± SD)	Middle (Mean ± SD)	End (Mean ± SD)
Before mitral valve replacement	Systolic arterial pressure (mmHg)	110 ± 15	110 ± 14	110 ± 15
	Diastolic arterial pressure (mmHg)	60 ± 8	62 ± 8	60 ± 80
	Heart rate (beats/min)	68 ± 10	70 ± 11	68 ± 12
After mitral valve replacement	Systolic arterial pressure (mmHg)	98 ± 14	99 ± 11	98 ± 12
	Diastolic arterial pressure (mmHg)	55 ± 10	56 ± 9	58 ± 9
	Heart rate (beats/min)	74± 14	77± 17	76± 15

Table 3: Tei index

	Mean	Std. Deviation	Std. Error Mean
Pre op Tei index	0.3212	.02057	.00291
Post op Tei index	0.3256	.01981	.00280
Paired Samples Test			
	T	df	Sig. (2-tailed)
Pre op Tei index - Post op Tei index	1.776	49	0.082

Table 4: Ejection Fraction.

	Mean	N	Std. Deviation	Std. Error Mean
Pre op EF	42.0200	50	7.12423	1.00752
Post op EF	47.0000	50	9.11827	1.28952
Paired Samples Test				
Paired Differences				
Pre op EF – Post op EF		Mean	Std. Deviation	Std. Error Mean
		4.98000	8.08246	1.14303
Pre op EF – Post op EF		T	df	Sig. (2-tailed)
		4.357	49	0.0001

was 0.3256 with a SD of 0.0028. The difference between pre-op and post-op Tei Index was statistically not significant. The mean EF in our study preoperatively was 42.0200 with a SD of 7.12423 and the mean EF post operatively was 47.00 with a SD of 9.11827 as shown in Table 4. The difference between pre-op and post-op EF was statistically significant.

DISCUSSION

Rheumatic mitral stenosis is one of the commonest valvular heart lesions in India and other developing countries.[1] The results of operation, morbidity, and mortality are governed not only by the mechanical defect but also by the state of the myocardium. A reduced left ventricular ejection fraction in the setting of mitral stenosis is relatively common, with prevalence of approximately 30%.[5]

There are several echocardiographic indices for the assessment of the left ventricular function. This observational studyinvolves the assessment of the utility of Tei Index and EF in measuring the perioperative cardiac function in patients with MS undergoing Mitral Valve Replacement. The aetiology of mitral stenosis in this study was rheumatic in 100% cases and 15% of these patients were on beta blockers, 10% on digoxin, 17% on frusemide and 5% on ACE inhibitors. The mean duration of cardiopulmonary bypass was 90 ± 22 minutes and the mean duration of aortic cross-clamping was 65 ± 18 minutes. This was comparable to the mean duration of cardiopulmonary bypass of 75 ± 18 minutes and the mean duration of aortic cross-clamping was 63 ± 20 minutes in the study conducted by N. Mabrouk-Zerguini, P. Le´ger et al.[2] During echocardiographic measurements, hemodynamic profile of the patients was stable. The major finding of the present study was the increase in LV EF after mitral valve replacement, whereas the Tei index remained unaffected by the surgical procedure. A reduced left ventricular ejection fraction in the setting of

mitral stenosis is relatively common, with prevalence of approximately 30%.[6]

Several studies examined left ventricular ejection performance by angiographic and hemodynamic variables in patients with MS, with some reporting reduced performance attributable to insufficient preload, afterload mismatch, and the effects of right ventricular pressure impaired diastolic filling, impaired myocardial contractility, and reduced passive compliance of poterobasal left ventricular myocardium from scarring or inflammation.[5] Abnormal passive elastic properties have also been reported in patients with severe MS arising from chamber atrophy due to unloading, myocardial fibrosis, right and left ventricular interaction, or internal restrictions due to the rigid mitral valve apparatus by Mayer et al.[6] In 1970, Stanley J. Heller et al [7] studied twenty-five patients with pure mitral stenosis and nine normal subjects by selective left ventricular cineangiocardiography. Left ventricular volumes were measured at end systole, throughout diastole, and at end diastole. Although filling curves showed that the left ventricles filled slowly in patients with mitral stenosis, normal end-diastolic volumes were attained and provided diastole lasted 400 msec. Despite normal end-diastolic volumes, end-systolic volumes were significantly larger ($P < 0.0005$) in the patients with mitral stenosis (av = 64.6 ml) than in normal subjects (30.8 ml). Correspondingly, left ventricular ejection fractions were significantly lower ($P < 0.0005$) in the patients with mitral stenosis (55.7%) than in the normal subjects (76.7%). Qualitative analysis of the cineangiocardiograms demonstrated that 20 patients with mitral stenosis had distortion, immobility, and rigidity of the posterobasal area of the left ventricle. They hypothesized that a rigid "mitral complex" immobilizes the posterobasal area of the left ventricle in patients with mitral stenosis, thereby impairing left ventricular contraction, and this impairment is an important factor in the reduced cardiac output of these patients. In 1973, Lawrence D. Horwitz et al[8] studied the effects of isometric exercise on left ventricular performance during cardiac catheterization in six patients with mitral stenosis and six patients without significant cardiac disease. Quantitative analyses of left ventricular cineangiograms were completed to correlate changes with the findings during exercise. During exercise, left ventricular function curves were abnormal in five of the six patients with mitral stenosis. In addition, ejection fractions were significantly lower in the group with mitral stenosis as compared with the normal subjects. The lower ejection fractions in the patients with mitral stenosis were due to localized abnormalities in the posterobasal and anterior left ventricular wall. They concluded that left ventricular function is abnormal in mitral stenosis due to localized wall motion abnormalities, which are probably due to fibrosis near or in the papillary muscles. M. Mohsen Ibrahim [9] in 1979, used echocardiography to examine the extent and significance of impairment in left ventricular function in 20 patients with rheumatic mitral stenosis. Indices of left ventricular performance - normalised mean rate of circumferential fibre shortening (Vcf), ejection fraction, normalised posterior wall velocity, and stroke volume were reduced. The impairment in left ventricular function was related to the degree of functional disability (NYHA), right ventricular dilatation, and left atrial enlargement. Vcf was inversely related to both the internal right ventricular diameter and the degree of left atrial enlargement. The normalised velocity of the interventricular septum and the maximum systolic and diastolic endocardial velocities were also reduced. These results suggest that the abnormalities in contractility of left ventricular myocardium are responsible for the impaired myocardial function in patients with mitral stenosis and that such impairment is clinically significant. Gash et al [10] in 1983 reported that the patients with MS usually exhibit reduced ejection phase indices of LV performance because of reduced preload. Gash et al postulated that patients with MS have an increased afterload because of reduced wall thickness, and that this relative increase in afterload is not adequately balanced by the Frank-Starling mechanism because of reduced LV diastolic filling. JM Dubroff et al [11] in 1983, found a pre-operative mean EF of 48% in MS patients in their study. In a study conducted by MH Crawford, J Souchek et al [10] in 1990, the mean preoperative EF in MS patients was 48%. All these studies were consistent with a reduced EF (mean 42%) in MS patients found pre operatively in our study. Our study showed a significant increase in EF after mitral valve replacement in MS patients from a mean of 42% pre operatively to a mean EF post operatively of 47%. In the study conducted by JM Dubroff et al[11] in 1983 showed a significant increase in ejection fraction from 41 ± 5 before bypass to 50 ± 7 after bypass ($p<0.05$), after correction of mitral stenosis. This finding was consistent with our results as well.

Although long-term effects have been studied, the immediate effect of surgery for acquired heart disease on left ventricular function is not well defined. Accordingly, 44 adults with acquired heart disease underwent intraoperative two-dimensional echocardiography with a gas-sterilized transducer before and immediately after cardiopulmonary bypass in the study conducted by JM Dubroff et al[11] in 1983. Ejection fraction was measured by short-axis area change at the maximum left ventricular cross section (SAAC-EF) and also by a method using multiple sections. In this study, they observed that relief of mitral stenosis resulted in an intraoperative increase in ejection fraction from 0.41 ± 0.05 to 0.50 ± 0.07 ($p < .05$), respectively. In the study conducted by MH Crawford, J Souchek et al [12] in 1990 there was no significant change in EF or EDV postoperatively in the MS patients. This might be because of the fact that the prosthetic valves used in

this study have a reduced orifice size compared with normal valves. Besides, other differences in myocardial preservation and operative technique may also play a role; these intra operative factors, however, are difficult to assess quantitatively. The left ventricular function before and after cardiac surgery may be influenced by a number of variables during the perioperative period. Thus the study observations concerning changes in ejection fraction must be assessed in light of the known hemodynamic effects of (1) anaesthesia, (2) myocardial preservation techniques, including hypothermia and cardioplegia, (3) cardiopulmonary bypass, and (4) changes in circulating hormone levels during and after surgery.

In the study conducted by Haque et al[13] in 1992 showed a decreased mean Tei index of 0.34 in MS patients. ICT, IRT, and ET were significantly shorter before surgery compared with control patients resulting from low aortic pressure, high left atrial pressure, and reduced stroke volume. As a result, Tei index in patients with MS was significantly decreased before surgery. This was consistent with our finding of a reduced mean Tei index of 0.32 pre operatively in MS patients. In our study, the mean Tei index preoperatively was 0.32 and the mean Tei index post operatively was 0.33.The difference between pre-op and post-op Tei index was not statistically significant. Nurcan Arat et al[14] in 2006, evaluated the effect of percutaneous mitral balloon valvuloplasty (PMBV) on global systolic and diastolic functions of the left ventricle with the use of the Tei index. The study included 76 consecutive patients (16 males, 60 females; median age 36 years; range 19 to 68 years) who underwent PMBV for isolated rheumatic mitral stenosis. Systolic and diastolic indexes were measured by pulsed Doppler tissue imaging echocardiography from the mitral lateral annulus and the Tei index was calculated before, and 48 hours and three months after PMBV. They found that concerning diastolic function parameters, there was an improvement in the maximum early diastolic velocity (p=0.001), early and late diastolic velocity ratio (p=0.02), and a decrease in the isovolumetric relaxation time (p=0.02) immediately after PMBV. Maximum systolic velocity (p=0.01) improved as a systolic function parameter. Left ventricular global function as assessed by Tei index did not improve significantly 48 hours and three months after PMBV. They concluded after PMBV, there was an insignificant change in the Tei index. Thus the findings were consistent with the study conducted by Nurcan Arat et al in 2006, which showed an insignificant change in the Tei index after correction of mitral stenosis. Haque et al [13] in 1992, designed a study to compare Tei index before and after the surgical valve replacement or repair to evaluate effects of valve dysfunction on Tei index. Participants consisted of 76 consecutive patients with aortic or mitral valve surgery Doppler Tei index were evaluated before and after the surgery by obtaining (a– b)/b, where *a* is the interval between the cessation and onset of Doppler mitral filling flow and *b* is the aortic flow ejection time. They found that Tei index significantly increased after surgery in patients with mitral stenosis (0.34 $\pm$ 0.03 to 0.39$\pm$0.04). They concluded that Tei index significantly changes after valve surgery especially in patients with AS. Considerations for the effects of valve dysfunction on Tei index are required for its application to evaluate ventricular function in patients with valve disease. In the presence of Mitral Stenosis, LV conditions are modified with a trend to decrease preload and increase afterload. Under these hemodynamic conditions, the assessment of myocardial contractility by ejection phase measurements may be inappropriate, as these are well known to be influenced by acute changes in loading conditions.

LIMITATIONS OF OUR STUDY

The changes found in our study expresses the effects of improved valve function and also the effects of changes in LV function by the surgery. These effects were not separated, therefore, pure effects of valve dysfunction on Tei index may not be clearly shown in this study. The current literature has most part focused on late postoperative LV function after valve surgery whereas; the early postoperative period to provide data at this critical stage is studied. Secondly, TEE measurements were performed under general anaesthesia with open chest and do not allow generalization of our results to conscious, spontaneously breathing patients with MS. Further, other differences in myocardial preservation and operative technique may also play a role; these intra operative factors, however, are difficult to assess quantitatively. Thirdly, the Tei index was calculated from pulse wave Doppler. Nonetheless, further investigation should consider the measurement of Tei index from tissue Doppler imaging, which is apparently less variable as recently reported. Fourth, EF by Fractional area change (FAC) has been evaluated. Among the ejection indexes, Simpson ejection fraction is the current gold standard. However, the relation between FAC and ejection fraction is usually quite good. In our study, the mean Tei index preoperatively was 0.3212 with a SD of 0.0206 and the mean Tei index post operatively was 0.3256 with a SD of 0.0028. The difference between pre-op and post-op Tei index was statistically not significant. The mean EF preoperatively was 42.0200 with a SD of 7.12423 and the mean EF post operatively was 47.00 with a SD of 9.11827. The difference between pre-op and post-op EF was statistically significant. Mitral Valve Replacement for Mitral valve Stenosis results in significant increase in Left Ventricular preload as well as distortion in Left Ventricular architecture. In contrast to Ejection Fraction, the Tei index remains unchanged after Mitral Valve Replacement, suggesting that this parameter is less influenced by changes in Left Ventricular loading conditions and shape.

In addition, its preoperative determination allows us to identify patients in whom a severe unsuspected systolic dysfunction could render weaning from cardiopulmonary bypass. Moreover it gives an estimate of combined systolic and diastolic function, which frequently co-exists and hence, is more reflective of overall cardiac dysfunction than systolic and diastolic measures alone.

CONCLUSION

Tei index is a better parameter to assess left ventricular function.

Conflict of interests: None declared

1st Author's contribution: Concepts, design, literature search, clinical studies, data acquisition, data analysis, manuscript preparation and editing.

2nd Author's contribution: Concepts, clinical studies, data acquisition, data analysis, manuscript editing

13rd Author's contribution: Literature search, clinical studies, data acquisition, data analysis, manuscript editing

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