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EFFECTS OF QRS DURATION ON MYOCARDIAL PERFORMANCE AS ASSESSED BY Z-RATIO AND TEI-INDEX IN CHRONIC HEART FAILURE PATIENTS

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Contribution
All the authors contributed significantly to the research that resulted in the submitted manuscript.

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ABSTRACT

Objective: We aimed to compare the effect of QRS duration on Tei-index, a measure of effective pump time and myocardial performance, and Z ratio.

Methodology: We retrospectively analysed the ECG and Echocardiographic data of 83 patients with stable chronic heart failure in cardiology department of a teaching hospital. Echocardiograms were recorded using a Hewlett Packard Sonos 2000 echocardiograph with a 2.5 MHz transducer.

Results: Tei-index and Z-ratio were previously reported3 within normal limits in normal controls (n=17). Tei-index was significantly increased in patients with heart failure but with normal activation (p <0.0001), but not the Z-ratio (p =0.4). Both Z-ratio and Tei-index were abnormal in dilated cardiomyopathy with LBBB (p<0.0001). There was a significant inverse correlation between the duration of QRS and Z-ratio (r=-0.58; p<0.0001). Similarly QRS duration is directly correlated with Tei-index (r=0.36; p=0.0008). Varying values of QRS duration have different effects on the Z-ratios. There is a significant difference in the Z-ratio of patients with QRS duration of <120 ms (Z-ratio 78±9), compared with QRS of >120 ms (Z-ratio 68±11), with a p-value of <0.0001. There was a significant difference in the Tei-index of patients with QRS of <120 ms, (0.56±0.19) compared to that of patients with QRS of >120 ms (0.66±0.18), (p=0.03).

Conclusions: There is a strong correlation between QRS duration and Z-ratio as well as with Tei-index. Tei-index is sensitive to the presence of DCM, whether or not activation is normal whereas Z-ratio is much more specific for electrical abnormalities. QRS duration has profound effects on the mechanical activity of the heart in systole and diastole in patients with chronic heart failure.

Key Words: Heart Failure, Left Bundle Branch Block, Dilated Cardiomyopathy, Systole, Diastole

INTRODUCTION

Electrical conduction of the heart and mechanical activity of the heart are much dependent upon each other. Changes in one may have tremendous effect on the other and may result in significant difference in the outcome of different diseases. Importance of ventricular activation and ventricular mechanics, have been initially mentioned by Wiggers in 1926[1]. In chronic heart failure (CHF) abnormal electrical conduction is usually associated with abnormal left ventricular functions. Different ECG parameters have differing effects on different echo parameters in systole as well in diastole. Not only the ejection fraction but also all the cardiac actions throughout the cardiac cycle have important functions in the efficiency of the heart. The validation of systolic time intervals as a means of studying left ventricular systolic function several decades ago demonstrated the potential value of measuring well defined time periods within the cardiac cycle. This approach was able to detect acute changes in cardiac structure due to the drugs or other interventions as well as associated left ventricular ejection fraction from the ratio of PEP/LVET (Pre ejection period / Left ventricular ejection time). This approach had disadvantages:-

a) Rate dependence of any interval that included LVET,

b) Unable to distinguish disturbances of activation from those of left ventricular disease itself.

Recently two new intervals have been introduced (a) Tei Index, and (b) Z Ratio. Z Ratio recently described as effective pump time of the heart in a cardiac cycle, and found to be low in patients with CHF[2]. Tei-index is a Doppler derived measure of cardiac performance[3]. Tei -index also shown to have some prognostic importance and clinical importance in identifying patients with chronic heart failure and to assess the severity of the disease, and patients with abnormal conduction and BBB have been excluded from that study[4]. In this study we examined the effect of QRS duration on LV function in terms of Z-ratio and Tie-index and also their inter-relationship in chronic heart failure patients. We also aimed to look into the effects of presence or absence of LBBB on Z-ratio and Tei-index values.

METHODOLOGY

92 consecutive patients of heart failure were recruited in cardiology department of a teaching hospital in cross sectional study. We also analysed the ECGs and echocardiograms of 17 normal controls. All patients underwent routine clinical and laboratory investigations. All had stable heart failure i.e.; no change in symptoms or medications in previous three months, in sinus rhythm with an enlarged heart and pulmonary congestion on chest x-ray. All had a left ventricular ejection fraction of $< 40\%$. Exclusion criteria included patients with significant structural valve disease or significant arrhythmias, frequent atrial or ventricular ectopics, and atrioventricular conduction disturbances. Patients on antiarrhythmic medication were also excluded from the study. Patients with presence of LBBB have QRS duration of more than 120 ms, broad slurred R wave in leads I, aVL, V5 and V6, and absence of septal q waves in V5 and V6[5], but broader QRS duration can also be due to the presence of some non-specific blocks are general intraventricular conduction delay, where only QRS duration is broad and other criteria of bundle branch block are not present. We analysed that data also according to the presence of LBBB and separately also with broad QRS complex with or without LBBB.

Echocardiograms: Echocardiogram examinations were performed by an experienced cardiologist. Two-dimensional guided M-mode recordings of LV minor axis were obtained from the conventional parasternal view with the patient in left semilateral position. End-diastole was taken as the onset of the q wave of the simultaneously recorded electrocardiogram and end-systole as the onset of the aortic component of the second heart sound (A2) on a superimposed phonocardiogram. LV ejection fraction was estimated using the equation $EF=(EDD^3-ESD^3)/EDD^3$ %. Left ventricular filling time was estimated from transmitral pulsed Doppler recordings and ejection time from pulsed Doppler at aortic valve cusps level.

Z-Ratio: Z-Ratio was calculated in all patients according to the Zhou et al[2], as the sum of left ventricular ejection and filling times, divided by the RR interval and expressed as percentage {Z ratio = [(LVET + LVFT) / RR] * 100}.

Tei-Index: Tei-index was calculated according to the Tei et al[3], as the sum of isovolumic contraction time (IVCT) and isovolumic relaxation time (IVRT) divided by ejection time (ET) (Tei-Index = IVRT + IVCT / ET).

Data was analysed using Statview 5.0 for Windows. Continuous variables were described as mean $\pm$SD. Differences in values and their significance were calculated using student unpaired t tests. Univariate regression was used to elucidate the relation between QRS duration and Z ratio, and Tei-index. Multiple regression analysis was also performed. A probability value of less than 0.05 was taken as statistically significant.

RESULTS

Clinical characteristics of the studied subjects and results of electrocardiographically and echocardiographically measured parameters are presented in table 1. Finally 83 patients were included in the study. Nine patients were excluded from the study because of artefacts on the ECG or echocardiographs. The mean age of 57 males and 26 females was 67.5 ± 11.8 years. Mean ejection fraction was $36\pm11\%$. Left ventricular end diastolic diameter was mean of 6.2±1.0 cms in the absence of any major wall motion abnormalities. Mean left ventricular end systolic diameter was 4.9±1.2 cms. QRS duration was <120 ms in 46 patients, and 37 patients have QRS duration of >120 ms. LBBB was present in 25 patients. Twelve patients have non-specific broad QRS duration (>120 ms).

Tei-Index: Normal of Tei-index in our control subjects (n=17) was 0.19±8. In the patients as a whole there was difference between patients with broader QRS complex (0.56±0.19) compared to that of those with QRS duration of <120 ms (0.66±0.18) (p = 0.03) (table 2). There was some moderate correlation between Tei-index and QRS duration (r = 0.36) (figure 4) (table 4).

Table 1: Patients Characteristics

	Mean	± SD
Age (years)	67.5	11.8
NYHA class	2.3	0.8
LVEF (%)	36	11
Heart rate (per minute)	76	15
SBP (mm of Hg)	122.2	22.2
DBP (mm of Hg)	75.2	10.6
LVEDD (cms)	6.2	1.0
LVESD (cms)	4.9	1.2
PR interval (ms)	181.0	35.4
QRS duration (ms)	115.7	26.0
QT interval (ms)	392.6	56.2
QTc interval (ms)	435.0	55.6
Z-ratio (%)	74.4	11.7
Tei-index	0.61	0.19

LVEF: left ventricular ejection fraction;
SBP: systolic blood pressure;
DBP: diastolic blood pressure;
LVEDD: left ventricular end diastolic diameter;
LVESD: left ventricular end systolic diameter;
SD: standard deviation.

QRS groups (ms):

1= 80-100, 2= 101-120, 3= 121-140, 4= 141-160, 5= >16

Z-Ratio: Normal values of Z-ratio in our control subjects was 80±3 %. Z-ratio was normal in patients with QRS duration of <120 ms (78.9%±9.9) with a P-value of <0.0001. But it was significantly lower in patients with QRS duration of >120 ms (68.9%±11.5). Z-ratio showed a stronger inverse correlation with QRS duration (r = - 0.58) than Tei index (figure 2). Presence of LBBB also have got significant effect on the values of Z-ratio (67.3%±9.2) compared to those

Table 2: Differences in mean values according to QRS values

	QRS <120ms mean ±SD	QRS >120 ms mean±SD	p-value
N	46	37	0.2
LVEDD (cms)	6.1±1.2	6.4±0.6	0.3
LVESD (cms)	4.8±1.7	5.2±1.3	0.01
LVEF (%)	38±12	28±13.4	<0.0001
Z-ratio (%)	78.9±9.9	68.9±11.5	0.03
Tei-index	0.56±0.19	0.66±0.18	

n: number;
LVEDD: left ventricular end diastolic diameter;
LVESD: left ventricular end systolic diameter;
LVEF: left ventricular ejection fraction.

Figure 1: Bar graphs sowing increase in Tei-index with graded increase in QRS duration

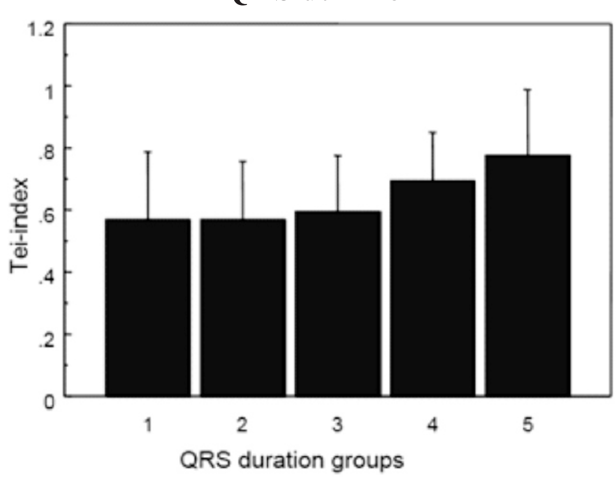


Fig 2. Regression plot for Tei-index and QRS duration

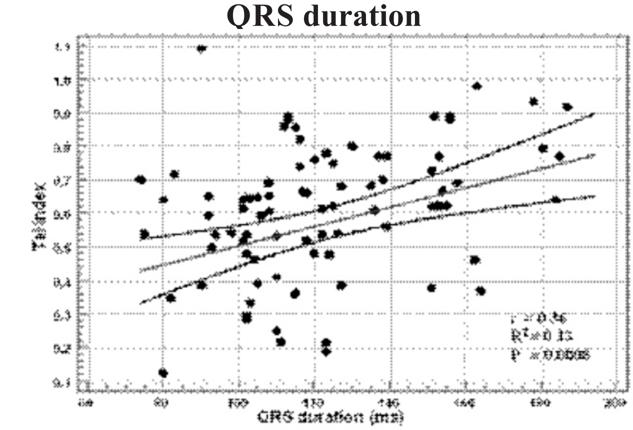


Table 3: Univariate regression models

	Z-Ratio (%)			Tei-index		
	Coef (95% CI)	P-value	R^2	Coef (95% CI)	P-value	R^2
QRS duration	-0.58(0.70-0.41)	<0.0001	0.33	0.36(0.15-0.53)	0.0008	0.13

Coef: regression coefficient; **R^2:** coefficient of determination; **CI:** confidence interval

without LBBB (77.2%±11.3) with a P-value of 0.0005.

Straight line is the regression line, curved lines shows the 95% confidence interval

Comparison of Z-ratio and Tei-index in normal controls, heart failure patients with or without LBBB: As shown in Figure 5 & 6, there is significant difference (p < 0.0001) between Tei-index (0.56±0.9) of heart failure patients with normal activation compared with that of normal controls (0.19±0.08), but this difference is not found (p = 0.4) in case of Z-ratio (78±9 %) in heart failure patients with normal activation vs normal controls (80±3 %). The presence of LBBB in patients with heart failure showed significantly higher Tei-index (0.65±0.19; p <0.0001) and lower Z-ratio (67±10 %; p <0.0001) comparing with normal controls. This difference was significant (p = 0.0001) in Z-ratio when compared with heart failure with normal activation but not significant (p = 0.1) in case of Tei-index in LBBB when compared with heart failure with normal activation.

Figure 3: Increase in QRS durtion according to the group leads to decrease in Z-ratio

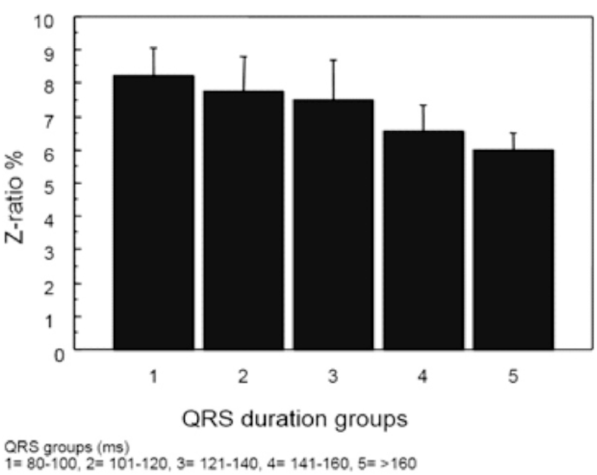


Figure 4: Regression plot for QRS duration and Z-ratio

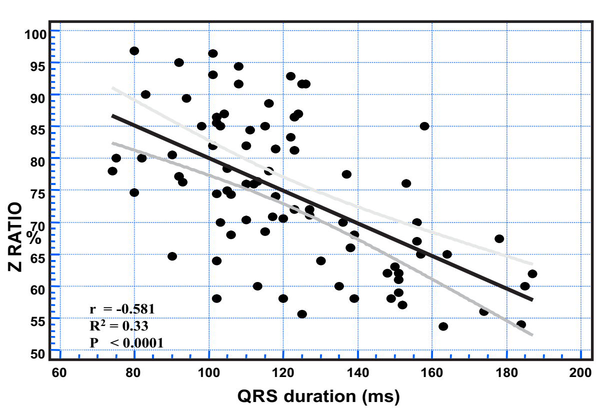


Table 4: Effect of Left bundle branch block

	no LBBB	LBBB	p-value
N	58	25	0.07
LVEDD (ms)	6.0±1.0	6.6±1.1	0.03
LVESD (ms)	4.8±0.9	5.6±1.2	0.04
LVEF %	39±16	31±13	0.001
Z-ratio (%)	79.2±11.2	66.3±8.9	0.3
Tei-index	0.60±0.21	0.65±0.19	

LBBB: left bundle branch block

Figure 5: Bar graph showing differences in Z ratio in different groups of patients

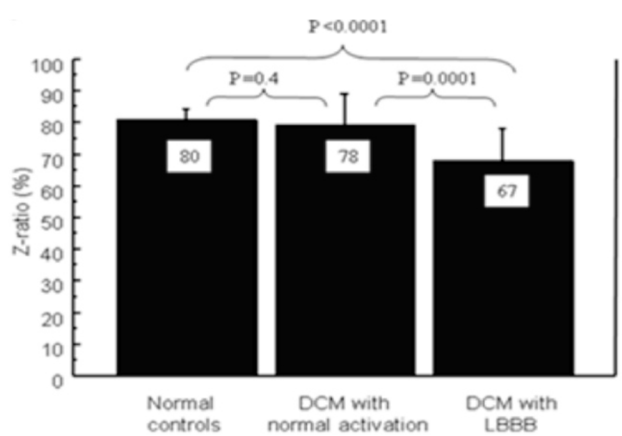
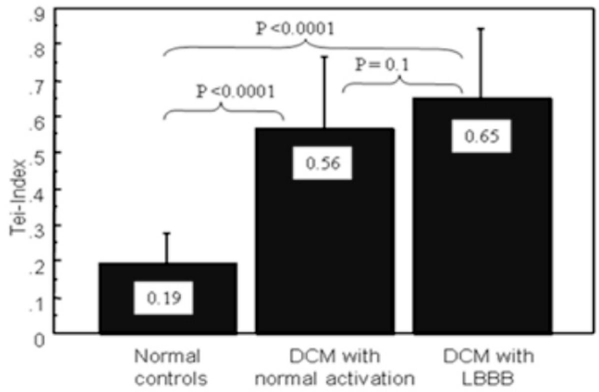


Figure 6: Bar graph showing Tei-Index in different groups of patients



DISCUSSION

Various conventional methods are used for functional evaluation and risk stratification in heart failure[8]. The Tei index is used as a reasonable index of global LV function because it simultaneously reflects systolic and diastolic LV function; and also allows prediction of prognosis of post-myocardial infarction in patients[9]. The conventional Tei index was originally calculated from measurement of time intervals at mitral inflow and LV outflow using pulsed wave Doppler[10]. Tei-index and Z ratio are both derived by measuring the left ventricular filling and ejection time from aortic and mitral pulsed Doppler traces. To the best of the authors' knowledge, the comparison of the Tei-index and Z ratio has not been studied previously in chronic heart failure patients, and there have been no studies to confirm the differences of Tei-index and Z ratio among patients with chronic heart failure. Tei-index expresses the ratio between total isovolumic and ejection times, while Z ratio the proportion of the cardiac cycle during which the left ventricle is either ejecting or filling. From their derivation it might be anticipated that their performance in differentiating patients with DCM form normal would be similar. Tei-index was independent of abnormal activation in patients with DCM regardless of activation time, and showed further sensitivity to QRS duration, whether expressed as continuous variable or whether a cutoff at 120 ms was considered. Z ratio was insensitive to ejection fraction but very sensitive to QRS duration. Thus there was a clear difference between the two.

Differences in their sensitivities lies in their derivation. Z ratio is derived by dividing total isovolumic time by RR interval, where as Tei-index is derived by dividing total isovolumic time by ejection time. Thus at any given RR interval, the sensitivity of the Tei index to ejection fraction compared to Z ratio more depend upon the short ejection time. This has been known for years from measurements of the systolic time intervals, and also been expressed as PEP / ET (PEP: pre ejection period) which is greatly increased in heart failure. Patients with LBBB undoubtedly had more severe left ventricular disease in terms of cavity size and ejection fraction. However most unlikely that difference in ejection fraction 39 vs 31 % was the cause of that in Z ratio, though it might have explained the small difference in Tei-index.

Limitations: This is not a prospective randomised study. Furthur studies are required in more number of patients with more detailed parameters may be including nuclear studies and comparisons. The LV measurements obtained from 2D-guided M-mode, and doppler echocardiography have several limitations, including sub-optimal accuracy in the presence of abnormal LV geometry, large inter-observer variability and poor inter-study reproducibility.

CONCLUSION

Our results confirm that the Tei-index is sensitive in detecting reduced ejection fraction. It has been claimed to be a measure of systolic and diastolic function, which may contribute to its sensitivity to left ventricular disease. Z ratio in contrast is insensitive to depressed ejection fraction, but very sensitive to abnormal activation. Tei-index is sensitive to left ventricular disease but little information about the nature of the underlying abnormality. Z ratio specifically to detect abnormalities of activation independent of ejection fraction, and interrelation between acute changes in left ventricular function and activation changes.

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