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Research Article

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The Effect of Left Ventricular Geometry on Myocardial Performance Index in Hypertensive Patients

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Abstract

Background: The relationship between Tei Index (TI) and left ventricular (LV) geometric patterns has not been previously well described. The present study therefore set out to describe the nature of this relationship. This study examined the association between the Tei index and left ventricular geometry among hypertensive Egyptian subjects.

Methods: This study included 70 subjects (60 hypertensive Patients and 10 control subjects). Hypertensive Patients and control subjects were referred from outpatient clinic to the Echocardiographic laboratory of Cardiovascular Department in Almataria Teaching Hospital between April 2017-November 2017. TI was defined as the sum of isovolumic contraction and relaxation times divided by the ejection time, and values of LV TI<0.40 were considered normal, while higher values were considered abnormal. Four patterns of LV geometry (normal, concentric remodeling, concentric LV hypertrophy and eccentric LV hypertrophy) were determined from the LV mass index and LV relative wall thickness. Statistical analysis was done using SPSS version 20.0. Bivariate correlation and stepwise multiple linear regressions were used to analyze the associations between TI and a number of variables.

Results: Among the hypertensive subjects, Concentric hypertrophy was the commonest pattern of abnormal geometry (36.7%), followed by eccentric hypertrophy (20%), and concentric remodeling was demonstrated in 15% of the hypertensive population. Only 28.3% of the hypertensive population had normal geometry. Hypertensive patients with normal geometry had the highest Tei index. Those with concentric hypertrophy had higher Tei index than those with concentric remodelling. However, there was no significant difference in the Tei index between those with eccentric and concentric hypertrophy. In correlation between MPI and Echocardiography variables of LVH of hypertensive patients in bivariate correlation had a direct statistically significant with LVPWDd, IVSDd, LVIDd, LVISd, LV mass & LVMI. The MPI had inverse significant correlation with EF and FS. While by using stepwise multiple linear regressions the predictor of MPI was the LV mass index.

Conclusion: This study has found that MPI is impaired in hypertensive patients before development of ventricular hypertrophy and in left ventricular hypertrophy is more prominent in concentric hypertrophy.

Keywords: Tei index; Hypertension; Left ventricle geometry; Echocardiography

Introduction

High BP was the leading cause of death and disability-adjusted life years worldwide. Because of the high prevalence of hypertension and its associated increased risk of CHD, stroke, and end-stage renal disease (ESRD), the population attributable risk of these outcomes associated with hypertension is high. In the population-based ARIC (Atherosclerosis Risk in Communities) study, 25% of the cardiovascular events (CHD, coronary revascularization, stroke, or HF) were attributable to hypertension [1].

The changes in left ventricular (LV) structure and geometry that evolve after myocardial injury or overload usually involve chamber dilation and/or hypertrophy. Such architectural remodeling can be classified as eccentric or concentric. Pressure overload of the left ventricle results in an increment in ventricular mass with a high relative wall thickness (RWT); the earliest change appears to be an increase in RWT before there is a detectable increase in LV mass. These architectural changes seen in concentric hypertrophy and concentric remodeling provide a mechanism for maintenance of normal LV systolic wall stress in the presence of a high systolic pressure. Such preservation of systolic wall stress allows maintenance of normal or near-normal LV systolic function and performance [2].

The combination of left ventricular mass index (LVMI) and relative wall thickness (RWT) were be used to identify different patterns of left ventricular geometry:

- Concentric hypertrophy (increased LVMI and RWT).
- Concentric remodelling (normal LVMI and increased RWT).
- Eccentric hypertrophy (increased LVMI and normal RWT).
- Normal geometry (Normal LVMI and RWT) [3].

The Tei index of myocardial performance is a combined index of systolic and diastolic dysfunction and has been shown to be a predictor of cardiovascular outcome in heart disease. The relationship between the Tei index and left ventricular geometry has not been well studied [4].

Myocardial performance index (MPI) was calculated as follows: (isovolumic contraction time+isovolumic relaxation time)/ejection time. The mean normal value of the Tei index is 0.39 ± 0.05 for the LV, values of the LV index<0.40 was consider as normal (Figure 1) [5].

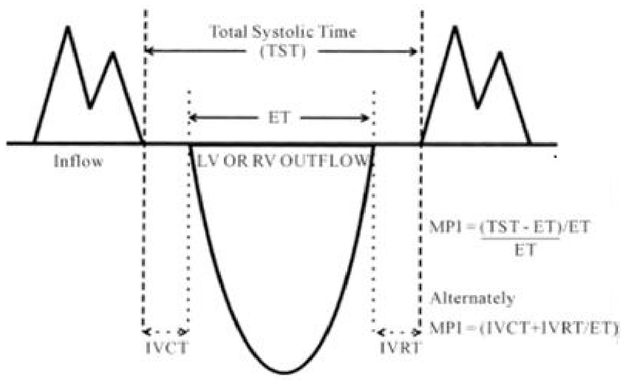

Figure 1: How to calculate Tei Index; IVCT: Isovolumic Contraction Time; IVRT: Isovolumic Relaxation Time; ET: Ejection Time; TST: Total Systolic Time; MPI: Myocardial Performance Index.

Methods

This study included 70 subjects (60 hypertensive Patients and 10 control subjects). Hypertensive Patients and control subjects were referred from outpatient clinic to the Echocardiographic laboratory of Cardiovascular Department in Almataria Teaching Hospital between April 2017-November 2017. All hypertensive patients had clinical BP ≥ 140/90 mmHg and/or use of antihypertensive therapy and were at least 18 years old.

Patients were excluded from the study if they had one or more of the following:

- History of chronic renal failure.
- Ischemic heart disease.
- Heart failure (excluded systolic heart failure by echocardiography).
- Valvular heart disease (significant causing LVH).

All hypertensive patients and controls were subjected to Full history taking, Clinical examination and Echocardiography. BP (Clinical blood pressure was measured at the time of echocardiography with a standard cuff (12-13 cm long and 35 cm wide) and mercury sphygmomanometer, after patients had rested for 3-5 min in sitting position. Average of two measurements was taken spaced by 1-2 min. Phase I and V (disappearance) Korotkoff sounds were used to identify systolic and diastolic BP, respectively [6]. Other clinical information obtained included weight (in kilograms), height (in centimetres) and body mass index(BMI) BMI=Weight (Kg) / Height $(m)^2$.

Echocardiography

All the subjects had transthoracic echocardiography done according to the recommendation of the American Society of Echocardiography. All echocardiography examinations were performed on a GE Vivid five ultrasound machine. Patients were placed in the left lateral position.

Left ventricular measurements such as left ventricular internal dimension in diastole (LVIDd) and systole (LVIDs), posterior wall thickness in diastole (PWTd), and interventricular septal thickness in diastole (IVSd). Left ventricular mass (LVM) was calculated from the measurements of the left ventricle (LV) using the equation:

LVM (g)=0.81 [1.04 (interventricular septal thickness+posterior wall thickness+LV end-diastolic internal dimension) 3–(LV end-diastolic internal dimension) 3]+0.6 [7].

LVM index (LVMI) was calculated as LVM/height $(m)^{2.7}$. Correcting LVM for height 2.7 has been shown to minimize the effect of gender, race, age and obesity on the validity of various parameters for the diagnosis of left ventricular hypertrophy (LVH), for which many parameters exist. LVH was defined as LVMI>51 $g/m^{2.7}$ for men or 47 $g/m^{2.7}$ in women [8].

LV geometry was determined after calculation of the relative wall thickness (RWT) using the formula: RWT=2(PWTd)/LVIDd .

RWT was considered abnormal if it was ≥ 0.45. Four left ventricular geometric patterns were described based on RWT and left ventricular mass index (LVMI): normal geometry, concentric remodelling, eccentric hypertrophy and concentric hypertrophy. LV geometry was defined as concentric hypertrophy (elevated LVMI and RWT), concentric remodeling (normal LVMI and elevated RWT), eccentric hypertrophy (increased LVMI and normal RWT) and normal geometry (normal LVMI and RWT) [4].

The Tei index reflects both systolic and diastolic function. It was defined as the sum of the isovolumic relaxation time and isovolumic contraction time divided by the ejection time obtained from the left ventricular inflow and outflow. The isovolumic relaxation time was determined from the apical five chamber view as the time from the end of left ventricular ejection to the beginning of the early mitral inflow (E) wave. Isovolumic contraction time was defined as the time from the peak of the R wave or the end of the late atrial filling (A) wave to the beginning of left ventricular ejection [9]. Values of LV TI <0.40 were considered normal, while higher values were considered abnormal.

Results

The clinical characteristics of the study population are shown in Table 1. The hypertensive and the control population were well matched in age and gender distribution. The clinical and echocardiography data of the studied hypertensive patients when compared with Age and sex matched normal subjects showed that hypertensive patients have highly statistically significant correlation regarding weight, BSA, LVM, LVMI, LV PWDd, LVIDd, LVIDs, ET, IVRT and MPI.

Table 2 shows the mean age and echocardiographic parameters among the four left ventricular geometric patterns. Concentric hypertrophy was the commonest pattern of abnormal geometry (36.7%), followed by eccentric hypertrophy (20%), and concentric remodeling was demonstrated in 15% of the hypertensive population. Only 28.3% of the hypertensive population had normal geometry. Hypertensive patients with normal geometry had the highest Tei index. Those with concentric hypertrophy had higher Tei index than those with concentric remodelling. However, there was no significant difference in the Tei index between those with eccentric and concentric hypertrophy.

In correlation between MPI and Echocardiography variables of LVH of hypertensive patients in bivariate correlation had a direct statistically significant with LVPWDd, IVSDd, LVIDd, LVISd, LV mass and LVMI. The MPI had inverse significant correlation with EF and FS (Table 3). While by using stepwise multiple linear regressions the predictor of MPI was the LV mass index (Table 3) (Figures 2 and 3).

Echocardiography parameters	Patients (N=60)	Control (N=10)	p-value
Age (years)	53.95 ± 9.58	49.80 ± 10.34	0.13
Gender F (%)	28 (46.7%)	4 (40.0%)	0.695
Hight (cm)	1.67 ± 0.08	1.68 ± 0.09	0.841
BMI [wt/(ht)^2]	34.04 ± 5.29	30.50 ± 4.76	0.021
LVPWDd (mm)	1.09 ± 0.21	0.82 ± 0.12	<0.001
IVSDd (mm)	1.10 ± 0.18	0.83 ± 0.12	<0.001
LVIDd (mm)	4.82 ± 0.59	3.92 ± 0.23	<0.001
IVCT (ms)	77.50 ± 18.37	37.20 ± 2.10	<0.001
IVRT (ms)	131.73 ± 50.31	79.10 ± 5.86	0.002
ET (ms)	264.97 ± 36.89	285.90 ± 4.28	0.079
LV mass (gm)	200.49 ± 72.67	95.64 ± 23.52	<0.001
RWT	0.46 ± 0.10	0.42 ± 0.06	0.263
LVMI (g/m$^{2.7}$)	50.80 ± 19.31	24.06 ± 6.64	<0.001
MPI	0.81 ± 0.26	0.41 ± 0.02	<0.001

Table 1: Clinical and echocardiographic parameters of study participants; LVIDd: Left Ventricular Internal Dimension in diastole; LVIDs: Left Ventricular Internal Dimension in systole; PWTd: Posterior Wall Thickness in diastole; ET: Ejection Time; IVCT: Isovolumic Contraction Time; IVRT: Isovolumic Relaxation Time; BMI: Body Mass Index; LVMI: Left Ventricular Mass Index; RWT: Relative Wall Thickness; F: Female.

Parameters	Normal geometry (N=17)	Concentric remodelling (N=9)	Eccentric hypertrophy (N=12)	Concentric hypertrophy (N=22)	p-value
Age (years)	51.41 ± 9.62	56.89 ± 6.09	63.08 ± 5.98	55.18 ± 10.37	0.042
LVPWDd	0.82 ± 0.11	1.18 ± 0.14	1.18 ± 0.18	1.21 ± 0.07	0.689
IVSDd	0.88 ± 0.06	1.04 ± 0.17	1.23 ± 0.11	1.21 ± 0.07	<0.001
LVIDd	0.35 ± 0.05	4.33 ± 0.45	5.67 ± 0.50	4.71 ± 0.32	<0.001
LVISd	4.62 ± 0.40	2.92 ± 0.36	3.74 ± 0.56	3.09 ± 0.40	<0.001
RWT	2.92 ± 0.41	0.55 ± 0.12	0.41 ± 0.03	0.52 ± 0.06	<0.001
LV mass	130.45 ± 29.70	167.53 ± 29.08	295.11 ± 81.39	216.48 ± 23.50	<0.001
LVMI	30.90 ± 5.84	38.86 ± 5.22	75.12 ± 19.10	88.78 ± 7.01	<0.001
IVCT	76.88 ± 15.63	68.08 ± 21.07	74.89 ± 19.16	78.86 ± 17.05	0.022
IVRT	169.59 ± 74.79	114.89 ± 29.13	120.33 ± 17.94	128.95 ± 26.56	0.046
ET	256.59 ± 40.82	263.22 ± 49.03	258.08 ± 27.55	255.00 ± 33.79	0.003
MPI	0.99 ± 0.34	0.64 ± 0.24	0.72 ± 0.12	0.78 ± 0.19	0.016

Table 2: Clinical and echocardiographic parameters among various left ventricular geometric patterns in hypertensives; this table shows statistically significant difference between LVH geometry according to age and echocardiography.

Parameters	Bivariate Correlation		Stepwise Linear Regression	
	r	p-value	Correlation coefficient	p-value
Age (years)	-0.191	0.144	-0.046	0.179
Weight (kg)	-0.046	0.728	-0.011	0.903
Hight (cm)	0.19	0.146	0.046	0.181
BMI [wt/(ht)^2]	-0.152	0.245	-0.037	0.304
BSA	0.023	0.863	0.005	0.207
Duration of HTN	-0.202	0.122	-0.048	0.151
LVPWDd	-0.5	<0.001	-0.12	0.482
IVSDd	-0.135	0.305	-0.032	0.378
RWT	-0.08	0.544	-0.019	0.674
LVIDd	0.426	0.014	0.102	0.113
LVISd	0.388	0.027	0.093	0.224
LVEDV	-0.146	0.265	-0.035	0.329
LVESV	-0.092	0.484	-0.022	0.6
EF%	-0.023	0.861	-0.006	0.723
FS	-0.032	0.81	-0.008	0.68
LV mass	-0.363	0.004	-0.165	0.132
LVMI	-0.376	0.003	-0.16	0.023

Table 3: The bivariate correlation between echocardiographic findings & MPI among all LVH patients and the regression model; Positive correlation and significant between MPI with LVIDd, LVISd, while LVPWDd, LV mass and LVMI negative correlation and significant.

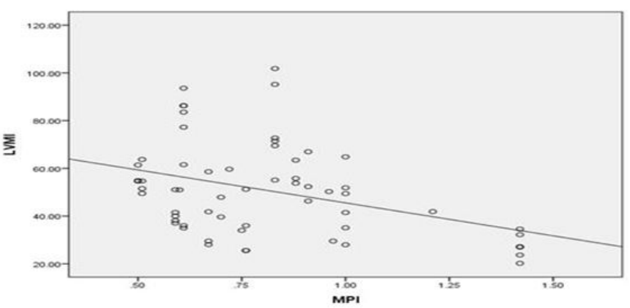

Figure 2: Scatter plot between MPI and LVMI.

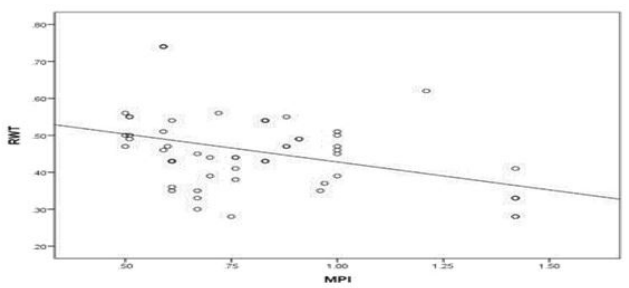

Figure 3: Negative correlation and significant between MPI and RWT with r-value (r=-0.388 and p-value 0.002).

Discussion

Left ventricular geometry and structural alterations occur in response to systemic hypertension in various pattern. This had been determining largely by whether pressure or volume overload is predominating.

Concentric hypertrophy, concentric remodeling may predominate due to the pressure overload whereas eccentric hypertrophy progressively takes over with increased left ventricular mass due to increase in volume overload. These geometric variations are associated with significant morbidity and mortality.

Left ventricular mass (LVM) plays an essential role in determination of left ventricular hypertrophy (LVH). The non-invasive wide application of echocardiography makes it a useful method for determination of LVM and to evaluate the LVH. Several studies have estimated a close statistical relationship between echocardiographic and angiographic calculations of LVM. Devereux et al. found good correlation between echocardiographic LVM and true anatomic LVM [7]. Left ventricular mass was calculated using the formula of Devereux and Reichek, this formula was dependent on three essential components, IVSd, LVIDd and PWTd. These components were also used in Relative wall thickness (RWT).

In our study, the total number of investigated hypertensive patients were 60 patients, 43 (71.7%) of them had a left ventricular hypertrophy (LVH) and 17 (28.3%) had no left ventricular hypertrophy (no LVH) or called normal geometry (NG).

We found the commonest pattern was concentric hypertrophy, followed by eccentric hypertrophy and finally concentric remodelling. Numerous studies have shown that systolic and diastolic time intervals are closely linked to systolic and diastolic left ventricular performance. Masugata et al. similarly reported that HR was the only clinical parameter that correlated with TI in a study on hypertensive patients ($r=+0.164$, $p<0.05$) [10].

In a different study, Masugata et al. reported that LVEF and LVMI were not associated with TI, while Yilmaz et al. reported that TI was associated with indices for LV geometry (LV mass index and RWT) [11].

In our study we found that the LVH group has a high IVSd, PWTd, LVM, and LVMI than the no LVH hypertensive patients. Also, patients with concentric LV hypertrophy had an increased LVM and LVMI compared to those with eccentric hypertrophy. These results are similar to those found by Mizuguchi et al. who had found greater LV wall thickness, greater LV mass in patients with concentric LV hypertrophy *vs.* eccentric LV hypertrophy [12].

In our study we found that myocardial performance index was higher in the patient group with (no LVH) compared to the controls one (0.99 ± 0.34 and 0.41 ± 0.02 respectively) and MPI was lower in LVH group compared to non LVH group of hypertensive patients, but still higher than normal (0.74 ± 0.18 and 0.99 ± 0.34) respectively, so the global left ventricle function was impaired in all hypertensive patients according to MPI.

MPI was impaired in all hypertensive patients before development of ventricular hypertrophy. This damage was the most evident in concentric hypertrophy geometric pattern.

In our study we found the mean myocardial performance index was high in different abnormal geometric patterns of LVH in hypertensive patients. The highest was noted among patients with concentric hypertrophy (CH) (0.78 ± 0.19), then EH (0.72 ± 0.12) and lowest in concentric remodelling patients CR (0.64 ± 0.24).

These finding were in agreement with the study by Akintunde et al. who found that MPI was 0.83 ± 1.0 in CH; 0.80 ± 0.2 in (EH) and 0.71 ± 0.2 in (CR) [4].

Ivanovic et al. also found that MPI was 0.68 ± 0.08 in (CH); 0.58 ± 0.06 in (EH) and 0.57 ± 0.06 in (CR) [13].

These finding was against Karaye who found no association between any LV geometric pattern and abnormal MPI [14]. There was also no relationship between LVH (eccentric LVH+concentric LVH) and abnormal MPI. Also Andersen et al. found that the index was similar in essential hypertension with geometric LV abnormality (concentric remodeling, eccentric hypertrophy or concentric hypertrophy) compared to patients without geometric changes (0.52 ± 0.11 *vs.* 0.51 ± 0.12) [15].

In correlating the MPI to the echocardiographic findings in the different geometric patterns of LVH patients, we found that, hypertensive patients with CH had MPI significantly correlated with LVIDD, LVISD LV mass and LVMI. While patients with CR had their MPI correlated with LVMI.

In our study, by using, bivariate correlation between myocardial performance index and echocardiographic variables in each LV geometry of LVH we found that MPI had a direct statistically significant with LV PWDd, IVSDd, LV IDd, Lv ISd, LV mass and LVMI. The MPI had inverse significant correlation with EF and FS.

While by using stepwise multiple linear regressions the predictor of MPI was the LV mass index. So we can say the myocardial performance index was independently high in left ventricular geometric patterns of hypertensive patients.

Conclusion

Therefore, it can be concluded that MPI is impaired in hypertensive patients before development of ventricular hypertrophy and in left ventricular hypertrophy is more prominent in concentric hypertrophy.

There was no relation between the left ventricular geometry and myocardial performance index. So the MPI was independently high in all left ventricular geometric patterns of hypertensive patients, and may reflected accurately the left ventricular systolic and diastolic dysfunction early before others conventional indices.

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