The Use of Left Ventricular Myocardial Stiffness Index as a Predictor of Myocardial Performance in Patients with Systemic Hypertension

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Abstract: **Background:** Patients suffering from systemic hypertension show morphological changes in the myocardial structure which in turn increase left ventricular stiffness. **Introduction:** Hypertension can lead to both systolic and diastolic abnormalities. There are several conventional indices for evaluating systolic function, such as ejection fraction, cardiac output, cardiac index and fractional shortening, while diastolic index can be assessed among others by transmitral Doppler wave pattern, isovolumic relaxation time, tissue Doppler and deceleration time. **Aim of the work:** To investigate the changes in the myocardium stiffness index for patients suffering from systemic hypertension, and to assess their left ventricular performance by TDI. **Material and methods:** a prospective study done over a period of one year that included established cases of hypertension diagnosed on the basis of history taking, and clinical examination, during the study period from (1/11/2014 to 30/12/2015). 150 subjects were divided into two groups, group A which included 100 hypertensive patients and group B which included 50 normal subjects. The two groups were evaluated by history taking, clinical examination and echocardiography. The data was analysed using Unpaired, Chi-square and Pearson correlation tests using GraphPad Instat & Med-Calc software, word processing data base and statistics programs. **Results**: The myocardial performance index has been shown to correlates directly with myocardial stiffness and also correlates significantly with other conventional indices. **Conclusion:** The diastolic stiffness was significantly higher in hypertensive patients compared to healthy subjects, also IMP appears to be a good measure of global left ventricular function (systolic and diastolic function), and is a sensitive and accurate evaluation of disease states. **Recommendations:** Another study is recommended to detect SI in patients with complicated hypertension particularly those with CHF.

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1. Introduction:

Hypertension remains the commonest cardiovascular risk factor. Left ventricular adaptations to hypertension include the development of left ventricular hypertrophy and several geometric alterations ***(Addo et al., 2007).***

These geometric variations are associated with significant morbidity and mortality, with various studies suggesting that subjects with concentric hypertrophy have a higher incidence of cardiovascular events, and those with eccentric hypertrophy are much more at risk of progressing to heart failure than those with other left ventricular geometric patterns ***(Akintunde et al., 2011).***

Other studies suggest that major cardiovascular events are similar between the four groups of geometric patterns (concentric remodeling, concentric hypertrophy, eccentric hypertrophy and normal pattern). However, left ventricular function has been shown to vary between the different left ventricular geometric patterns ***(Adamu et al., 2009).***

Alterations in chamber stiffness may reflect changes in passive myocardial stiffness as well as in other factors such as loading conditions, wall thickness, and LV geometry ***(Watanabe et al., 2011).***

Hypertension can lead to both systolic and diastolic abnormalities. There are several conventional indices for evaluating systolic function, such as ejection fraction, cardiac output, cardiac index and fractional shortening, while diastolic index can be assessed among others by transmitral Doppler wave pattern, isovolumic relaxation time, tissue Doppler and deceleration time. These indices are specific for systolic or diastolic function and each is associated with significant limitations with regard to their interpretation/relevance to clinical status and haemodynamic state ***(Akintunde et al., 2011).***

The myocardial performance index is a combined index of systolic and diastolic function and has been shown to correlates directly with myocardial stiffness and also correlates significantly with other conventional indices ***(Mizuguchi et al., 2010).***

Thus we conducted this study to investigate the changes in the myocardium stiffness index for patients suffering from systemic hypertension, and to assess their left ventricular performance by TDI.

2. Material and methods:

A prospective study done over a period of one year that included established cases of hypertension diagnosed on the basis of history taking and clinical examination, during the study period from (1/11/2014 to 30/12/2015). 150 subjects were divided into two groups, group A which included 100 hypertensive patients and group B which included 50 normal subjects. The two groups were evaluated by history taking, clinical examination and transthoracic echocardiography which left ventricular internal dimensions at diastole (LVIDd) and systole (LVIDs) will be measured, using M-mode echocardiography Pulse wave Doppler tracing of the transmittal flow velocity will be obtained from the apical four chamber view measurement of the early mitral velocity E and the late velocity A at atrial contraction. Mitral annulus velocity measurements will be obtained from the apical four-chamber view by tissue Doppler image, using a 1 - 2 mm sample volume placed at the lateral side of the mitral valve annulus. The TDI mitral annular velocities will be measured including the early annular velocity (Ea). All TDI velocities will be taken as an average of the lateral readings of five cardiac cycles. The mean values of Ea velocities will be used to calculate the E/Ea ratio. Myocardial diastolic stiffness index will be calculated using the equation of (Stiffness index = [(E/Ea)/LVIDd]) ***(King, et al, 2008).*** By using the apical view at aortic valve isovolumetric contraction time (IVCT), isovolumetric relaxation time (IVRT) and ejection time (ET) were measured from the interval between two mitral inflow periods (Figure 1), several investigators used IMP to assess left ventricle function, Most of them showed that IMP gives a good assessment of left ventricular dysfunction and its severity. IMP can be calculated by using the equation that: IMP = (IVCT + IVRT)/ET.

3. Results:

The present study included two groups, group A which included 100 hypertensive patients and group B which included 50 normal subjects.

Table (1) Comparison between patients and controls regarding the demographic data

		Patients (n=100)		Controls (n=50)	Student t test	
					t	p
Age (Years)		48.6 ± 10.3		45.5 ± 12.4	1.5	**0.13**
					Chi-square test	
					X2	**P**
Sex	**Male**	44 (44.0 %)		26 (52.0 %)	0.86	**0.36**
	Female	**56 (56.0 %)**		**24 (48.0 %)**		

This table shows no statistically significant differences between patients and controls regarding the demographic data.

Table (2) Comparison between patients and controls regarding echocardiographic data

	Patients (n=100)	Controls (n=50)	Student t test	
			t	p
LVEDD	4.9 ± 0.3	4.7 ± 0.3	2.5	**0.14**
LVEDS	3.5 ± 0.2	3.2 ± 0.4	-1.72	**0.044***
FS	34.7 ± 1.6	35.6 ± 3.2	-1.7	**0.09**
EF	**65.2 ± 2.0**	**66.1 ± 3.4**	**-1.6**	**0.1**

This table shows that patients had significantly higher LVEDS when compared with controls.

Table (3) Comparison between TDI parameters in patients and controls

	Patients (n=100)	Controls (n=50)	Student t test	
			t	p
E	71.1 ± 6.3	72.5 ± 3.9	-1.55	**0.12**
A	74.5 ± 7.5	58.5 ± 4.6	15.9	**0.0001***
E/A	0.97 ± 0.14	1.2 ± 0.09	-13.9	**0.0001***
Ea	10.2 ± 1.5	13.3 ± 1.0	-14.7	**0.0001***
E/Ea	7.1 ± 1.0	5.4 ± 0.5	12.4	**0.0001***
IVRT	94.1 ± 8.4	78.1 ± 7.8	11.2	**0.0001***
IVCT	62.0 ± 4.8	57.4 ± 5.9	5.03	**0.0001***
ET	**264.8 ± 16.5**	**305.1 ± 43.4**	**-6.33**	**0.0001***

This table shows statistically significant differences between patients and controls regarding TDI parameters.

Table (4): Comparison between patients and controls regarding SI and IMP

	Patients (n=100)	Controls (n=50)	Student t test	
			t	p
SI	1.45 ± 0.23	1.15 ± 0.14	10.1	**0.0001***
IMP	**0.59 ± 0.07**	**0.44 ± 0.04**	**15.4**	**0.0001***

This table shows that patients had significantly higher SI and IMP when compared with controls.

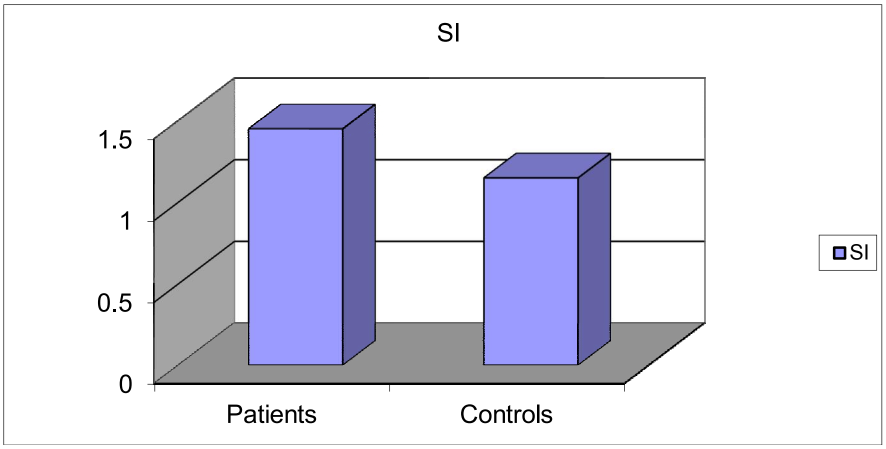

Fig. (1) SI in the studied groups **(P value < 0.0001)**

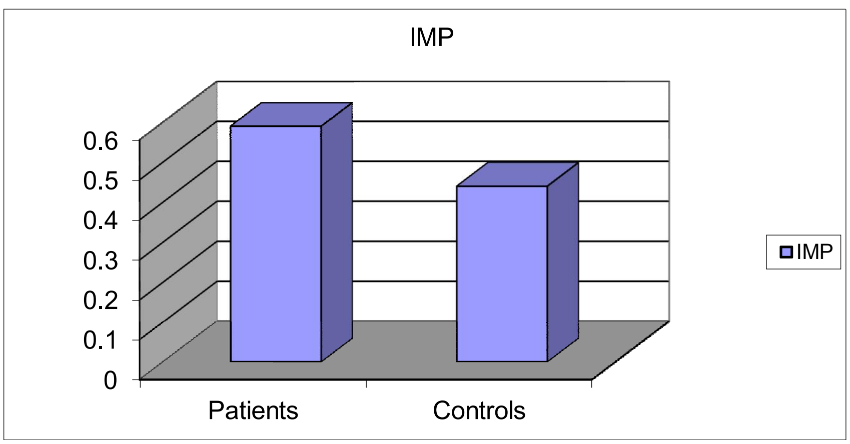

Fig. (2) IMP in the studied groups **(P value < 0.0001)**

Table (5) Relation between SI and the demographic data in the studied patients

		Pearson's correlation		
		r	p	
Age		**0.3**	**0.002***	
			Student t test	
			t	**p**
Sex	**Male**	**1.44 ± 0.24**	**-0.69**	**0.49**
	Female	**1.47 ± 0.23**		

This table shows a significant correlation between age and SI in the studied patients.

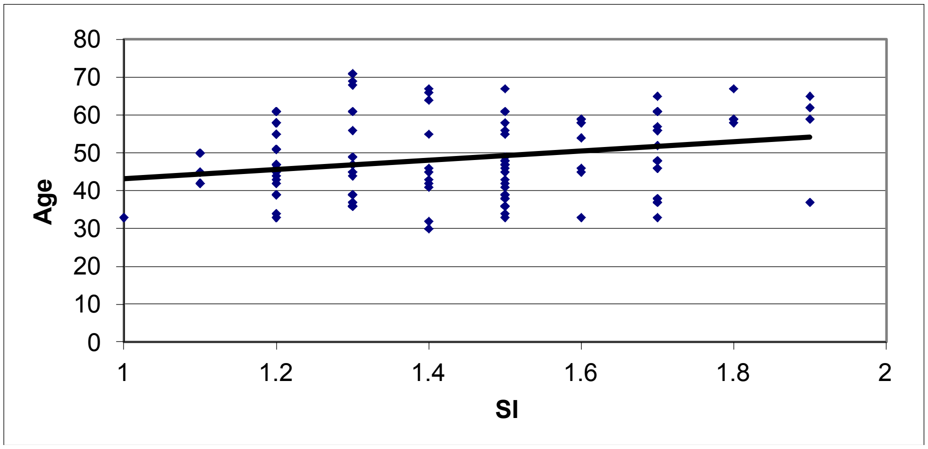

Fig. (3) Correlation between SI and Age (r = 0.3and P value is 0.0002)

Table (6) Relation between SI and TDI parameters

	Pearson's correlation	
	r	**p**
E	0.2	**0.04***
A	0.23	**0.02**
E/A	-0.016	**0.86**
Ea	-0.73	**0.0001***
E/Ea	0.93	**0.0001***
IVRT	0.17	**0.083**
IVCT	0.22	**0.027***
ET	**-0.24**	**0.015***

This table shows significant direct correlation between SI and E, A E/Ea and IVCT and inverse correlation with Ea and ET.

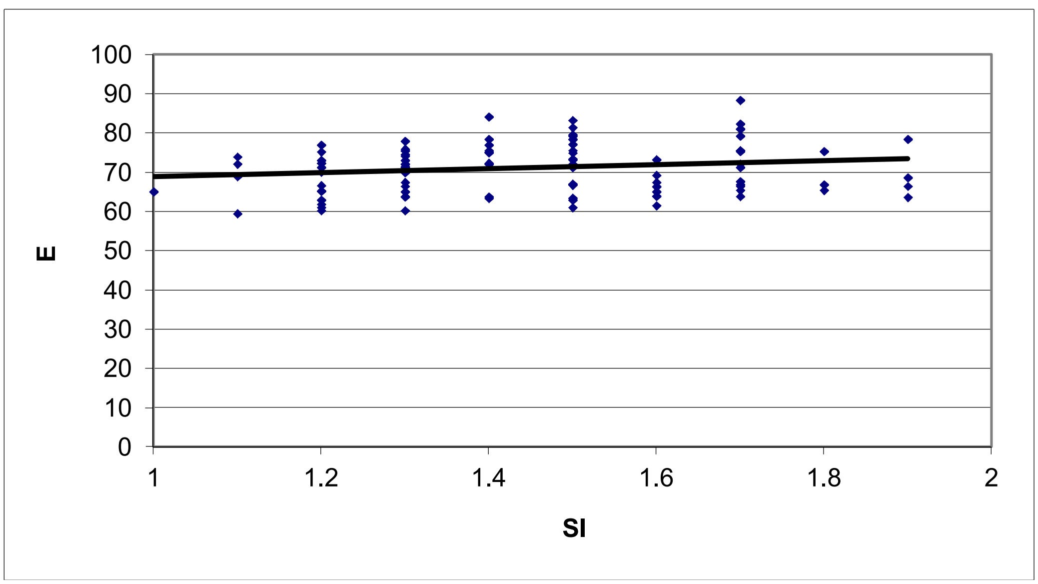

Fig. (4) Correlation between SI and E (r = 0.2and P value is 0.04)

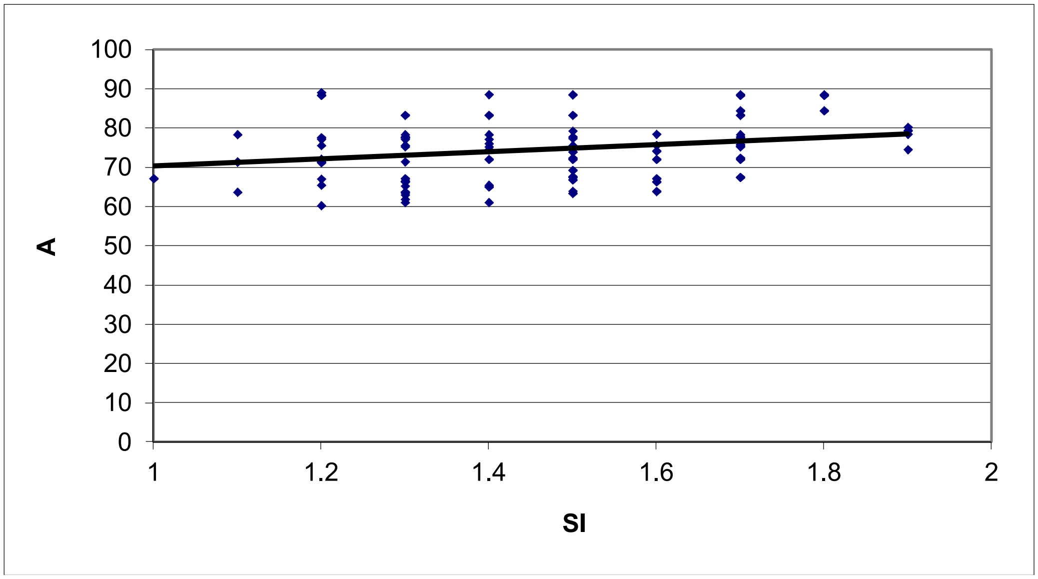

Fig. (5) Correlation between SI and A (r = 0.23and P value is 0.02)

Table (7) Relation between SI and IMP

	Pearson's correlation	
	r	**p**
IMP	**0.26**	**0.01***

This table shows significant direct correlation between SI and IMP.

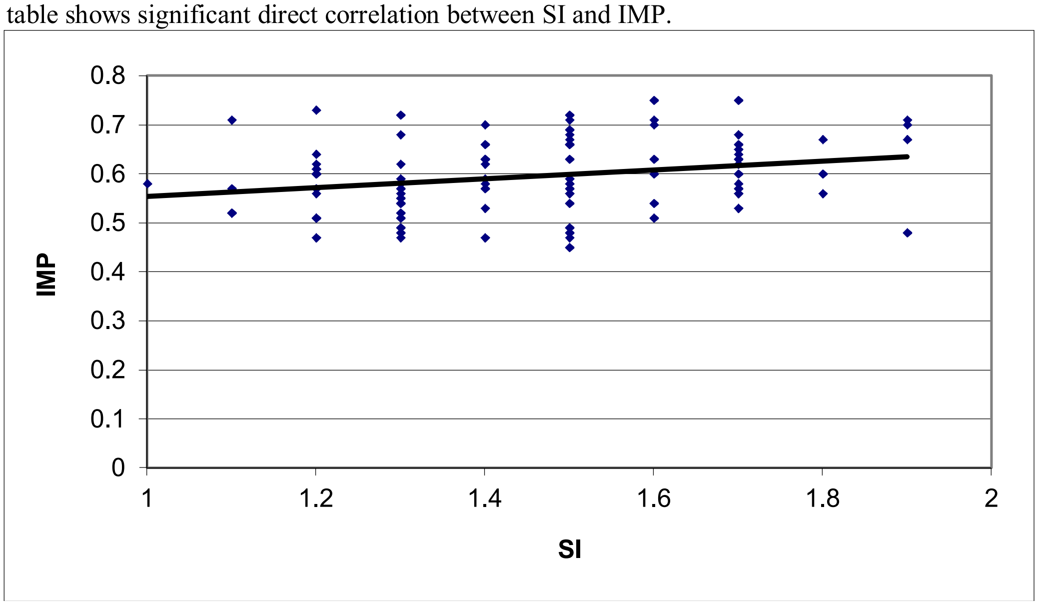

Fig (6) Correlation between SI and IMP (r = - 0.26and P value is 0.01)

4. Discussion:

Systemic hypertension is a common cardiovascular problem that cannot be fully treated with existing non-pharmacologic and pharmacologic measures and it has significant morbidity and mortality including left ventricular dysfunction ***(Burke et al., 2012).***

These include increased left ventricular mass which identifies hypertensive patients at increased risk of major cardiac and cerebrovascular events ***(Verdecchia et al., 2007).*** So, identifying LVH is a fundamental step in evaluating hypertensive patients ***(Cuspidi et al., 2007).***

Also, assessment of left ventricular (LV) diastolic function should be an integral part of a routine examination of hypertensive patient. Left ventricular diastolic dysfunction (LVDD) occurs frequently and is associated to heart disease. Doppler echocardiography is the best tool for early LVDD diagnosis ***(Palmiero et al., 2015).***

Furthermore, LV myocardial stiffness is considered to be an essential myocardial diastolic property independent of loading conditions. Despite its potential importance, it is still unknown whether or how these novel indexes can predict post-discharge outcomes for patients admitted for CHF ***(Watanabe et al., 2011).***

Myocardial performance index (MPI) is a Doppler echocardiographic parameter defined as the sum of the isovolemic contraction and relaxation times divided by the ejection time. It is considered as a reliable parameter to assess global left ventricular function ***(Correale et al., 2011).***

The present study aims to investigate the changes in the myocardium stiffness index for patients suffering from systemic hypertension, and to assess their left ventricular performance by TDI.

The study included 100 patients with systemic hypertension in addition to 50 healthy controls. Both groups were matched regarding age and sex distribution. All participants were subjected to careful history taking, thorough clinical and cardiac examination. In addition, they were submitted to echocardiographic examination using conventional and tissue Doppler echocardiography.

In the present study, hypertension grade was I in 71 patients, II in 23 patients and III in 6 patients. Hypertension was controlled in 64 patients and not controlled in 36 patients. This is in accordance with the study of ***Ebid et al., (2014)*** who studied the role of the pharmacist as a health care provider and the implementation of a pharmaceutical care model to improve medications adherence, BP control, knowledge and quality of life (QOL) in a sample of Egyptian patients suffering from hypertension. In their study, blood pressure control was achieved in 60.0 % of cases among 280 included patients.

In addition, it was shown that patients had significantly higher LVEDS when compared with controls. This is in accordance with the study of ***Li et al., (2014)*** and ***Liu et al., (2015)*** who found that hypertensive patients had significantly higher LVEDs when compared with normal controls.

Comparison between the studied groups regarding TDI parameters had shown significant differences between patients and controls regarding most parameters. This is in harmony with the study of ***Galanti et al., (2010)*** who evaluate the role of Pulsed Wave Tissue Doppler Imaging in differentiating pathological from physiological LVH in the middle-aged population. In addition, the study of ***Adebayo et al., (2008)*** who evaluated the utility of the tissue Doppler echocardiographic technique in characterising diastolic and systolic functions in untreated native black African hypertensive subjects and found similar results.

Comparison between patients and controls regarding SI and IMP had shown that patients had significantly higher SI and IMP when compared with controls.

This is in agreement with the study of ***Yilmaz et al., (2004)*** who investigated the relationship between the myocardial performance index (MPI) and left ventricular (LV) geometry in hypertensive patients. In their study, MPI, which is a marker of systolic and diastolic ventricular function, was measured in 64 hypertensive patients and in 15 healthy persons (Control). Results showed that a higher MPI was found in all patients compared with the controls.

In addition, the study of ***Tan et al., (2006)*** studied left ventricular function in hypertensive patients by using this index. A group of 40 hypertensives and 16 controls were included. MPI was significantly higher in NLVH and LVH groups than in control group, and in LVH group than in NLVH group.

In another study, ***Masugata et al., (2009)*** compared the MPI between hypertensive and normotensive patients and examined independent determinants of the Tei index in hypertensive patients with preserved LV systolic function. Results showed that patients had significantly higher MPI when compared with controls.

In addition, the study of ***Akintunde (2012)*** evaluated the correlation of the MPI with other conventional indices of systolic and diastolic function among Nigerians with hypertensive heart failure.

The present study found a significant correlation between SI and patients age, As founded This in the study of ***Wassenaar et al., (2015)*** who assess reproducibility in measuring left ventricular (LV) myocardial stiffness in volunteers throughout the cardiac cycle using MR elastography (MRE) and to determine its correlation with age. They noted that mycoardial stiffness is correlated to patients age.

Conclusion:

- The diastolic stiffness was significantly higher in hypertensive patients compared to healthy subjects. This may be due to the fact that patients with hypertension experienced certain morphologic and structural changes of the left ventricle including left ventricular hypertrophy reducing LV compliance and increasing myocardial stiffness.
- From the results it can be concluded that IMP appears to be a good measure of global left ventricular function (systolic and diastolic function), and is a sensitive and accurate evaluation of disease states.
- LV stiffness index is correlated directly with patients age and MPI.

Recommendations:

Another study is recommended to detect SI in patients with complicated hypertension particularly those with CHF, also another study is recommended to declare the influence of antihypertensive treatment on SI.

Limitations:

Relatively small sample size and the need for a suitable acoustic window to carry out studies of acceptable quality, however, if the echocardiographist has been trained in Doppler echocardiography images and the equipment used is technologically suitable, these limitations are purely relative. We have to take into account the intrinsic limitations of the technique such as: Dependency on the angle of incidence (this requires the best possible alignment between the ultrasound beam and the main displacement vector of the wall analysed), the changing situation of the sample volume and its variable position during the cardiac cycle.

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