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Myocardial performance index- an adjunctive echocardiographic indicator for assessment of global left ventricular function

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Abstract:

Objective: *The purpose of the study is to estimate the correlation between myocardial performance index (MPI) and global left ventricular function (both systolic and diastolic).*

Background: *In the diagnosis of patients with left ventricular dysfunction, prediction of both left ventricular systolic and diastolic functions are vital elements. Because systolic and diastolic function frequently coexist, it is hypothesized that a combined measure of left ventricular chamber performance may be more reflective of overall cardiac function than systolic and diastolic measures alone. Traditionally, assessment of left ventricular function is focused on measurement of left ventricular ejection fraction (LVEF). But it is load dependent and sensitive to the alterations in preload and after-load. However, myocardial performance index (MPI) demonstrates supremacy over older established indexes.*

Methods: *This cross-sectional analytical study was conducted in the Department of Cardiology of United Hospital limited and Evercare Hospital Dhaka since September, 2018 to August, 2020. Total 500 patients were included considering inclusion and exclusion criteria. The sample population was divided into four groups: Group–I: Normal adult people with good LV function (LVEF: ≥55%). Group–II: Patients with mild LV systolic dysfunction (LVEF: 45- 54%), Group–III: Patients with moderate LV systolic dysfunction (LVEF: 35-44%) & Group–IV: Patients with severe LV systolic dysfunction (LVEF: <35%). Then LVEF and MPI values were correlated.*

Results: *In this study 500 patients were enrolled. The mean age of the study group was 56.37±12.25, among them male were 358 (71.6%) & female were 142 (28.4%). 302 (60.4%) were hypertensive, 231 (46.2%) were diabetic, 101 (20.2%) having positive family history of CAD, 161 (32.2%) are current smoker, 282 (56.4%) dyslipidaemic & 48 (9.6%) were asthmatic. The mean LVEF of the groups were: 63.74±2.96, 48.80±2.78, 39.19±2.47 & 28.00±5.04 respectively. The mean MPI of the groups were: 0.145±0.135, 0.221±0.165, 0.217±0.169 & 0.222±0.150 which were statistically significant. Analysis showed that patients with highest level of MPI had severe left ventricular systolic dysfunction (LVEF <35%) and vice versa-the patients with the lowest levels of MPI had preserved systolic function (LVEF ≥ 55%).*

Conclusion: *The study has enabled the research team to conclude that lesser the LV ejection fraction level, higher the myocardial performance index and thus more severe is the LV systolic dysfunction.*

Keywords: *Doppler echocardiography, left ventricular ejection fraction, myocardial performance index, bi-plane modified Simpson's method.*

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I. Introduction

Recent studies have documented the frequent coexistence of systolic and diastolic dysfunction in people[1-2]. The systolic dysfunction is reflected in a decrease in left ventricular ejection fraction and a prolongation of the pre-ejection and shortening of the ejection phases of the cardiac cycle[3-6]. The diastolic dysfunction is reflected in alterations in pattern of the inflow velocity of the left ventricle in early and late diastole[7,8] as well as the prolongation of the relaxation phase of the cardiac cycle[9]. ST-elevation myocardial infarction (STEMI) is a leading source of cardiovascular death and thus accounts for a high burden on health care services worldwide. According to the heart disease and stroke statistics update 2016 of the American Heart Association (AHA), the estimated annual incidence of coronary attack in America is approximately 660000 new attacks and 305000 recurrent attacks[10]. Left ventricular (LV) systolic function is an important prognostic factor, associated with increased mortality in patients with STEMI[11,12]. LV function is measured by Two-dimensional (2D) echocardiography, M-mode echocardiography, Doppler echocardiography, and 3D echocardiography, both during systole as well as diastole[13]. A LV function is assessed by LV systolic function and diastolic function. Traditionally, assessment of LV function is focused on measurement of left ventricular ejection fraction (LVEF) and measurement of peak blood flow velocities during rapid filling (E wave) and atrial systolic contraction (A wave) represented the initial foray into the non-invasive assessment of diastolic ventricular function, which varies with age in normal subjects and is exquisitely sensitive to alterations in loading conditions. Both of them have not correlated with severity of symptoms, exercise capacity, myocardial oxygen consumption also unable to distinguish patients with clinical heart failure from those without heart failure, with equivalent ventricular dysfunction. Main limitations of LVEF are the load dependency, sensitivity to the alterations in preload and after-load and the geometrical assumptions involved in estimation of LVEF may not be appropriate in conditions like myocardial infarction where considerable alteration in the shape of LV occurs[14-16]. In 1995, Tei et al, proposed an index of myocardial performance (Tei index) that evaluates the LV systolic and diastolic function in combination. It demonstrates clear advantages over older established indexes and prognostic value in idiopathic dilated cardiomyopathy, cardiac amyloidosis and primary pulmonary hypertension[17,18]. The present study was designed to test whether a combined measure of systolic and diastolic function may improve the accuracy in detecting left ventricular global dysfunction over that determined by measures of systolic and diastolic function alone. This index of left ventricular dysfunction takes advantage of the ease of measurement of the isovolumetric and ejection phases of the cardiac cycle that becomes available in the echocardiographic Doppler recording of the mitral and aortic flow velocity profile[19].

II. Methods

Study population

This cross-sectional analytical study was conducted in the Department of Cardiology of United Hospital limited and Evercare Hospital Dhaka since September, 2018 to August, 2020. Total 500 patients were included considering inclusion and exclusion criteria. Purposive sampling was done using a structured case record form.

Study population was divided into four groups to study and compare the index of combined systolic and diastolic myocardial performance with several more systolic and diastolic parameters.

Group-I comprised of 148 normal individuals (79 males, 69 females having mean age of 52.01±14.20 years) in whom complete Doppler examinations were available. All of the study population of this group was asymptomatic, had a normal physical examination, chest Roentgenogram, electrocardiogram and two-dimensional echocardiogram.

Group-II consisted of 188 patients (147 males, 41 females having mean age of 56.66±11.14 years) from the echocardiographic laboratory database, selected on the basis of H/O myocardial infarction (both STEMI and NSTEMI), and ejection fraction (EF) between 45-55%.

Group-III consisted of 109 patients from the echocardiographic laboratory database, selected on the basis of H/O myocardial infarction (both STEMI and NSTEMI), and ejection fraction (EF) 35-44% **(**84 males, 25 females having mean age of 55.35±12.50 years).

Group-IV consisted of 55 patients from the echocardiographic laboratory database, selected on the basis of H/O myocardial infarction (both STEMI and NSTEMI), and ejection fraction (EF) <35% (48 males, 07 females having mean age of 61.47±11.15 years).

All the study subjects were selected on the basis of following inclusion and exclusion criteria.

a) Inclusion Criteria:

- Asymptomatic healthy people came for cardiac health check-up.
- Patients with unstable angina.
- Patients with ST segment elevation myocardial infarction.
- Patients with Non- ST segment elevation myocardial infarction.

b) Exclusion Criteria:

- Patients with valvular heart disease and congenital heart disease.
- Patients had major non- cardiovascular disorder causing elevation of Troponin-I such as severe renal impairment, prolonged immobilization, major surgery, chest trauma, myocarditis (pericarditis), acute pulmonary embolism, prolonged tachyarrhythmia.
- Any systemic infection.
- Patients were under chemotherapy on discovery of malignancy.
- Patient not willing to get themselves enrolled in study.

Before examination a detailed briefing about the purpose of the study was given to the subjects and written consents were taken for all of the study population.
Total 500 cases were enrolled in the study after qualifying the inclusion & exclusion criteria.

Study procedures

All patients with MI received guideline directed medical therapy at the time of admission. All patients were undergone for either primary PCI or thrombolytic (tenecteplase or streptokinase). All patients underwent conventional estimation of ejection fraction and LV end- systolic volume by a Bi-plane modified Simpson's method.

Echocardiographic examination

A complete two-dimensional pulsed wave, continuous wave and colour flow Doppler echocardiographic examination using ***Vivid E9 Pro of General Electronics Inc. Limited, USA*** was performed[20,21]. Left ventricular dimensions were measured at mid-ventricular level from the two- dimensional guided M-mode echocardiogram obtained by directing the cursor perpendicularly to the para sternal short axis view. Left ventricular ejection fraction (LVEF) was measured by using Bi-plane modified Simpson's volumetric method because of pronounced segmental asynergy in some patients.

Doppler examination

The mitral velocity inflow pattern was recorded from the apical four chamber view with the Pulsed wave Doppler sample volume positioned at the tip of mitral leaflets during diastole. Following this the left ventricular outflow velocity was recorded from the apical long axis view with the pulsed wave Doppler sample volume positioned just below the aortic annulus. Doppler colour flow imaging was used to semi- quantitate mitral regurgitation.

Echo/ Doppler measurements

For echo/ Doppler parameters three consecutive beats were measured and averaged for each parameter. **Figure 1** shows a schema for analysis of Doppler time intervals. Mitral closure-to-opening interval (a) is the time from the cessation to the onset of mitral in-flow. Ejection time (ET) was measured as the duration of left ventricular outflow (b). Isovolumetric Contraction Time (ICT) + Isovolumetric Relaxation Time (IRT) was obtained by subtracting 'b' from 'a' and an index: (ICT+IRT)/ET was derived as (a-b)/b. To compare this index to traditional parameters IRT, ICT and Pre-ejection period (PEP) were also measured. IRT was measured as (c-d) by subtracting the interval between the Electrocardiography (ECG) R wave and the cessation of left ventricular outflow from the interval (c) between the R wave and the onset of mitral flow. ICT was obtained by subtracting IRT from (a-b). PEP was measured from the onset of the QRS waveform to the onset of left ventricular outflow.

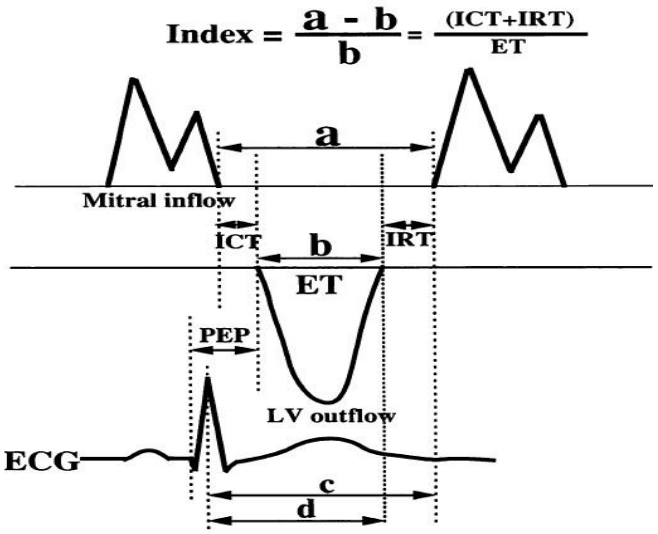

Figure 1: Schema of Doppler time intervals. The index (ICT+IRT)/ET is derived as (a-b)/b, where 'a' is the interval between cessation and onset of the mitral inflow and 'b' is the ejection time (duration of left ventricular outflow). IRT (isovolumetric relaxation time) is measured as (c-d), where 'c' is the interval between the ECG 'R' wave and the onset of mitral flow, and the 'd' is the interval between the R wave and the cessation of the left ventricular outflow. ICT (isovolumetric contraction time) is obtained by subtracting IRT from (a-b). PEP (pre-ejection period) is the interval from the onset of the QRS waveform to the onset of left ventricular outflow[22].

Peak velocities of mitral inflow in early diastole (E) and late diastole from atrial filling (A) were measured. The deceleration time (DT) was measured as time from the peak E velocity to the intercept of the deceleration of flow with the baseline. DT was not measured in patients with summated E and A waves. Mitral regurgitation was diagnosed by colour Doppler echocardiography and the severity of mitral regurgitation semi-quantitated from the area of the maximum regurgitant jet[23].

Variables studied:

Age, Sex, BMI, Smoking, Hypertension, Diabetes Mellitus, Dyslipidemia, F/H of CAD, Heart rate, Blood pressure (systolic, diastolic & mean), Troponin-I, BNP, ECG changes, Different echo parameters (both systolic & diastolic) and Myocardial performance index (MPI).

The data were processed and analyzed by computer software SPSS (Statistical package for social science) Version 23. Level of significance was considered as p value less than 0.05 ($p < 0.05$).

Statistical Method and analysis:

Continuous data were expressed as mean ± SD. Categorical data were analyzed with x^2 test. Student's t" test was used for analysis of continuous variables. Comparison between groups was done by unpaired t-test.

III. Results

This cross-sectional analytical study was conducted in the Department of Cardiology of United Hospital limited and Evercare Hospital Dhaka since September, 2018 to August, 2020. Total 500 patients were included considering inclusion and exclusion criteria. Purposive sampling was done using a structured case record form. Study population was divided into four groups to study and compare the index of combined systolic and diastolic myocardial performance with several more systolic and diastolic parameters.

Table I: Age distribution of the study population (n=500)

Age Group	Group-I		Group-II		Group-III		Group-IV		p-Value
	No	%	No	%	No	%	No	%	
20-30	12	8.1	1	0.5	2	1.8	0	0.0	
31-40	23	15.5	12	6.4	16	14.7	2	3.6	
41-50	29	19.6	47	25.0	21	19.3	8	14.5	**<0.001[s]**
51-60	43	29.1	68	36.2	36	33.0	16	29.1	
61-70	28	18.9	39	20.7	23	21.1	20	36.4	
71-80	13	8.8	18	9.6	10	9.2	5	9.1	

81-90	0	0.0	2	1.1	1	0.9	4	7.3
Above 90	0	0.0	1	0.5	0	0.0	0	0.0
Mean ± SD	52.01±14.20		56.66±11.14		55.35±12.50		61.47±11.15	
Overall	56.37±12.25							

s means significant

Group-I: Patients having good LV systolic function with LVEF≥55%
Group-II: Patients having mild LV systolic dysfunction with LVEF: 45-54%
Group-III: Patients having moderate LV systolic dysfunction with LVEF: 35-44%
Group-IV: Patients having severe LV systolic dysfunction with LVEF<35%

Table I showed the age distribution of the study population. Majority of the study population were in the 51-60 years age group. Then 71-80 years group & 41-50 years group subsequently. Statistical analysis showed significant age difference between the groups (p<0.05).

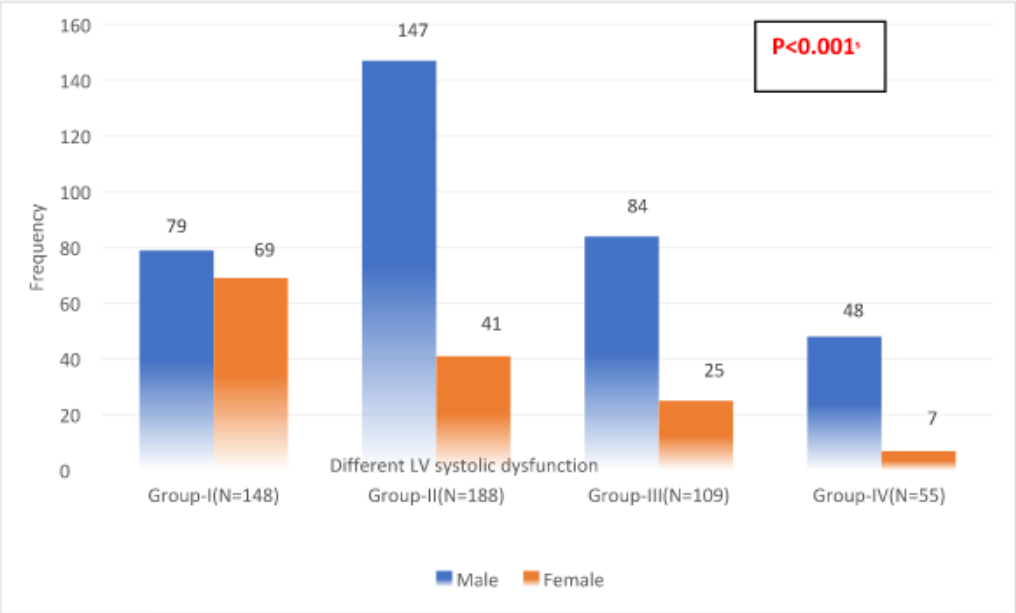

Figure 2: Sex distribution of the study population (n=500)

Figure 2 showed the sex distribution of the study population. Majority of the study population were male (358, 71.6%). Statistical analysis showed significant sex difference between the groups (p<0.001).

Table II: Anthropometric distribution of the study population (n=500)

Anthropometric Parameter	Group-I	Group-II	Group-III	Group-IV	p-Value
BMI	26.06±4.99	24.84±3.37	25.77±3.75	24.63±3.64	**0.015ˢ**

s means significant

Group-I: Patients having good LV systolic function with LVEF≥55%
Group-II: Patients having mild LV systolic dysfunction with LVEF: 45-54%
Group-III: Patients having moderate LV systolic dysfunction with LVEF: 35-44%
Group-IV: Patients having severe LV systolic dysfunction with LVEF<35%

Table II showed the anthropometric parameter distribution of the study population. It showed group-I people were more obese than rest of the groups. Statistical analysis showed significant difference between the groups (p<0.05).

Table III: Risk factor analysis of the study population (n=500)

Risk Factors		Group-I		Group-II		Group-III		Group-IV		p-Value
		No	%	No	%	No	%	No	%	
HTN	No	66	44.6	65	34.6	47	43.1	20	36.4	0.228[ns]
	Yes	82	55.4	123	65.4	62	56.9	35	63.6	
Diabetes	No	100	67.6	92	48.9	60	55.0	17	30.9	**<0.001[s]**
	Yes	48	32.4	96	51.1	49	45.0	38	69.1	
FH of CAD	No	120	81.1	151	80.3	83	76.1	45	81.8	0.747[ns]
	Yes	28	18.9	37	19.7	26	23.9	10	18.2	
Smoking	Non smoker	125	84.5	111	59.0	51	46.8	33	60.0	**<0.001[s]**
	Smoker	17	11.5	73	38.8	53	48.6	18	32.7	
	Ex- smoker	6	4.1	4	2.1	5	4.6	4	7.3	
Dyslipidaemia	No	92	62.2	64	34.0	42	38.5	20	36.4	**<0.001[s]**
	Yes	56	37.8	124	66.0	67	61.5	35	63.6	
Bronchial Asthma	No	124	83.8	174	92.6	102	93.6	52	94.5	**<0.013[s]**
	Yes	24	16.2	14	7.4	7	6.4	3	5.5	

s means significant
ns means not-significant

Group-I: Patients having good LV systolic function with LVEF≥55%
Group-II: Patients having mild LV systolic dysfunction with LVEF: 45-54%
Group-III: Patients having moderate LV systolic dysfunction with LVEF: 35-44%
Group-IV: Patients having severe LV systolic dysfunction with LVEF<35%

Table III showed the risk factor analysis of the study population. It showed majority of the study population were hypertensive & dyslipidaemic. Then diabetic, current smoker & asthmatic. Statistical analysis showed diabetic, dyslipidaemia, smoking & bronchial asthma were significantly different between the groups ($p<0.05$).

Table IV: Sub-group analysis of dyslipidaemia among the study population (n=500)

Lipid Profile	Group-I	Group-II	Group-III	Group-IV	p-Value
Total Cholesterol	158.64±37.70	187.39±47.18	174.02±48.63	179.56±50.54	**<0.001[s]**
LDL	102.11±32.72	120.91±37.60	112.91±38.33	119.24±42.06	**<0.001[s]**
HDL	33.27±5.28	34.64±5.86	35.55±7.47	35.75±5.85	**<0.001[s]**
Triglyceride	150.25±83.73	184.15±92.70	177.08±121.95	167.71±110.19	**<0.018[s]**

s means significant

Group-I: Patients having good LV systolic function with LVEF≥55%
Group-II: Patients having mild LV systolic dysfunction with LVEF: 45-54%
Group-III: Patients having moderate LV systolic dysfunction with LVEF: 35-44%
Group-IV: Patients having severe LV systolic dysfunction with LVEF<35%

Table IV showed the sub-group analysis of dyslipidaemia among the study population. It showed majority of the group-II were high in total cholesterol, LDL & triglyceride but low in HDL. The highest HDL was seen in group-IV people. Statistical analysis showed significant difference between the groups ($p<0.05$).

Table V: Cardiac profile of the study population (n=500)

Cardiac Profile	Group-I	Group-II	Group-III	Group-IV	p value
Heart Rate	78.76±10.83	78.60±13.36	82.28±17.30	90.04±20.06	**<0.001[s]**
Systolic BP	127.34±18.14	127.90±21.13	126.01±20.99	119.73±23.26	**<0.048[s]**
Diastolic BP	78.82±10.16	79.57±12.45	78.90±12.63	74.18±15.95	**<0.040[s]**
Mean BP	94.99±11.67	95.68±14.39	94.60±14.05	89.36±17.66	**<0.031[s]**

s means significant

Group-I: Patients having good LV systolic function with LVEF≥55%
Group-II: Patients having mild LV systolic dysfunction with LVEF: 45-54%
Group-III: Patients having moderate LV systolic dysfunction with LVEF: 35-44%
Group-IV: Patients having severe LV systolic dysfunction with LVEF<35%

Table V showed the cardiac profile among the study population. It showed all parameters are important factors to influence global cardiac function. Statistical analysis showed significant difference between the groups ($p<0.05$).

Table VI: Cardiac biomarker level of the study population (n=500)

Parameter	Group-I	Group-II	Group-III	Group-IV	p-Value
Troponin-I	0.87±4.95	16.34±19.26	16.30±19.18	18.27±17.14	**<0.001**[s]
BNP	17.36±5.78	131.60±253.08	105.15±249.41	80.27±154.69	**<0.001**[s]

s means significant

Group-I: Patients having good LV systolic function with LVEF≥55%
Group-II: Patients having mild LV systolic dysfunction with LVEF: 45-54%
Group-III: Patients having moderate LV systolic dysfunction with LVEF: 35-44%
Group-IV: Patients having severe LV systolic dysfunction with LVEF<35%

Table VI showed the Troponin-I & BNP level of the study population. It showed people of the group-IV had the highest level of Troponin-I but group II had the highest BNP level. Statistical analysis showed significant difference between the groups ($p<0.05$).

Table VII: ECG changes of the study population (n=500)

ECG Change	Group-I		Group-II		Group-III		Group-IV		p-Value
	No	%	No	%	No	%	No	%	
Normal	127	85.8	34	18.1	12	11.0	3	5.5	
ST depression	5	3.4	32	17.0	13	11.9	5	9.1	
T inversion	8	5.4	41	21.8	9	8.3	7	12.7	
AMI	0	0.0	45	23.9	40	36.7	17	30.9	**<0.001**[s]
OMI	0	0.0	27	14.5	30	27.5	21	38.2	
BBB	1	0.7	7	3.7	4	3.7	1	1.8	
Others	6	4.1	3	1.6	1	0.9	1	1.8	

s means significant

Group-I: Patients having good LV systolic function with LVEF≥55%
Group-II: Patients having mild LV systolic dysfunction with LVEF: 45-54%
Group-III: Patients having moderate LV systolic dysfunction with LVEF: 35-44%
Group-IV: Patients having severe LV systolic dysfunction with LVEF<35%

Table VII showed the ECG changes among the study population. It showed statistically significant difference of different ECG changes between the groups ($p<0.05$).

Table VIII: Echo profile of the study population (n=500)

Echo Parameters	Group-I	Group-II	Group-III	Group-IV	p-Value
LVIDd	43.95±5.16	48.70±5.83	51.09±7.10	57.62±7.71	**<0.001**[s]
LVIDs	28.72±3.45	35.05±5.49	40.22±7.12	48.91±8.53	**<0.001**[s]
LVEF	63.74±2.96	48.80±2.78	39.19±2.47	28.00±5.04	**<0.001**[s]
E/A	1.096±0.501	1.006±0.385	1.174±0.774	1.372±0.812	**<0.001**[s]
Mitral DT	166.07±47.14	169.06±33.85	165.24±37.66	147.78±44.04	**<0.007**[s]
Diastolic Filling Time	381.09±115.92	357.63±88.34	350.33±90.81	328.40±95.16	**<0.004**[s]
Pre- Ejection Period	142.67±26.23	155.13±23.56	156.97±27.55	143.96±28.86	**<0.001**[s]
Ejection Time	323.84±46.19	293.76±40.27	297.17±48.28	292.71±39.86	**<0.001**[s]
PEP/ET	0.450±0.104	0.537±0.098	0.545±0.131	0.497±0.106	**<0.001**[s]
ICT	84.89±17.32	91.69±16.70	88.24±15.55	82.73±20.04	**<0.001**[s]
IRT	91.09±19.45	104.38±19.54	98.26±17.88	94.58±23.15	**<0.001**[s]
ICT+IRT	175.98±30.52	177.07±29.99	186.61±27.31	196.31±36.06	**<0.001**[s]
ICT/ET	0.270±0.056	0.320±0.073	0.300±0.067	0.290±0.073	**<0.001**[s]
MPI	0.15±0.14	0.21±0.17	0.22±0.15	0.22±0.17	**<0.001**[s]

s means significant

Group-I: Patients having good LV systolic function with LVEF≥55%
Group-II: Patients having mild LV systolic dysfunction with LVEF: 45-54%
Group-III: Patients having moderate LV systolic dysfunction with LVEF: 35-44%
Group-IV: Patients having severe LV systolic dysfunction with LVEF<35%

Table VIII showed the echo parameters among the study population. It showed group-IV of the study population had the majority of the lowest indices of cardiac function & highest MPI level. On the other hand, group-I study population had the highest indices of cardiac function but lowest MPI level. Statistically significant difference was found between the groups ($p<0.05$).

Table IX: Mitral Regurgitation profile of the study population (n=500)

MR Profile	Group-I		Group-II		Group-III		Group-IV		p-Value
	No	%	No	%	No	%	No	%	
Nil	81	54.7	71	37.8	30	27.5	10	18.2	
Trivial	55	37.2	87	46.3	55	50.5	25	45.5	**<0.001[s]**
Mild	11	7.4	23	12.2	19	17.4	18	32.7	
Moderate	1	0.7	7	3.7	5	4.6	1	1.8	
Severe	0	0.0	0	0.0	0	0.0	1	1.8	

s means significant

Group-I: Patients having good LV systolic function with LVEF≥55%
Group-II: Patients having mild LV systolic dysfunction with LVEF: 45-54%
Group-III: Patients having moderate LV systolic dysfunction with LVEF: 35-44%
Group-IV: Patients having severe LV systolic dysfunction with LVEF<35%

Table IX showed the mitral regurgitation profile among the study population. It showed majority had trivial to mild regurgitation. Statistically significant difference was found between the groups ($p<0.05$).

Table X: Multi-variate regression analysis of the study population (n=500)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.998	.775		5.156	.000
	Age of Patient	-.005	.002	-.079	-2.467	**.014[s]**
	Sex of Patient	-.129	.056	-.075	-2.305	**.022[s]**
	BMI of Patient	.002	.006	.009	.293	.770
	Hypertension	.020	.048	.013	.419	.676
	Diabetes	-.139	.072	-.089	-1.947	.052
	Smoking	.056	.044	.041	1.278	.202
	Dyslipidaemia	.127	.060	.081	2.120	**.035[s]**
	Bronchial Asthma	.084	.075	.031	1.123	.262
	Total Cholesterol	.000	.001	-.013	-.198	.843
	LDL	.001	.001	.033	.588	.557
	HDL	.005	.004	.043	1.400	.162
	Triglyceride	.000	.000	.005	.142	.887
	Troponin-I	.009	.001	.203	6.800	**.000[s]**
	BNP	.000	.000	-.039	-1.216	.225
	Chest X-ray	.000	.070	.000	-.004	.997
	ECG Change	.087	.016	.190	5.502	**.000[s]**
	LVIDd	.013	.010	.121	1.261	.208
	LVIDs	-.028	.013	-.308	-2.252	.167
	LVEF	-.028	.005	-.429	-6.314	**.000[s]**
	MR	-.011	.029	-.011	-.378	.705
	Pre- Ejection Period	.005	.002	.155	1.847	.065
	Diastolic Filling Time	-.001	.000	-.078	-2.496	**.013[s]**
	Ejection Time	-.001	.002	-.075	-.716	.474
	PEP/ET	-1.111	.668	-.165	-1.663	.097
	ICT	.081	.038	1.799	2.139	**.033[s]**
	IRT	.081	.038	2.105	2.142	**.033[s]**
	ICT+IRT	-.080	.038	-3.236	-2.126	**.034[s]**
	MPI	.385	.163	.079	2.359	**.019[s]**

s means significant

Table X showed the multi-variate regression analysis of the significant variables of the study population. It showed age, sex dyslipidaemia, troponin-I, ECG changes, LVIDs, LVEF, Diastolic filling time, ICT, IRT, ICT + IRT & MPI were statistically significant confounding variables.

Table XI: Uni-variate regression analysis of the study population (n=500)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.291	.187		12.274	.000
	Age of Patient	.003	.002	.072	1.783	.075
	Sex of Patient	-.029	.045	-.027	-.654	.513
	Dyslipidaemia	-.014	.048	-.014	-.293	.770
	Troponin-I	.008	.001	.179	5.478	**.000$**
	ECG Change	-.002	.003	-.067	-.746	.456
	LVEF	-.034	.003	-.517	-11.715	**.000$**
	Diastolic Filling Time	.000	.000	.032	.825	.410
	ICT	-.032	.031	-1.096	-1.038	.300
	IRT	-.022	.030	-.900	-.729	.466
	ICT+IRT	.023	.030	1.466	.767	.444
	MPI	.748	.131	.238	5.696	**.000$**

s means significant

Table XI showed the uni-variate regression analysis of the significant confounding variables of the study population. It showed Troponin-I, LVEF & MPI were statistically significant confounding variables.

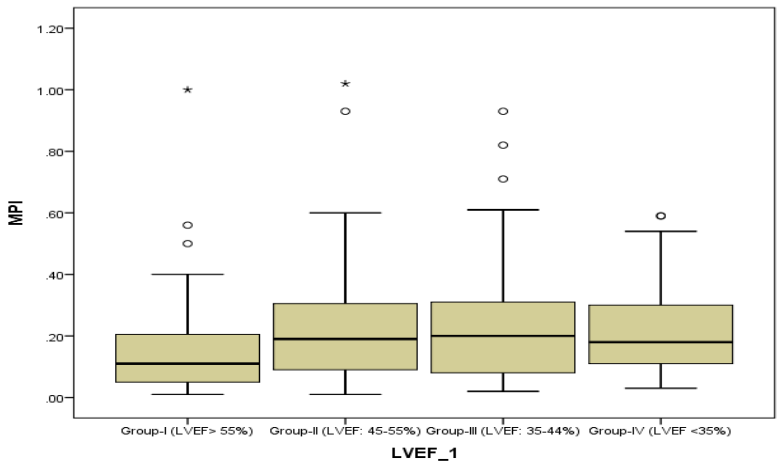

Figure 3: Box plot showing the relation of MPI & LVEF of the study population (n=500)

Figure 3 showed the box plot which showing the relation between MPI & left ventricular systolic function assessed by LVEF.

Figure 4: Correlation between HR & (ICT + IRT) of the study population (n=500)

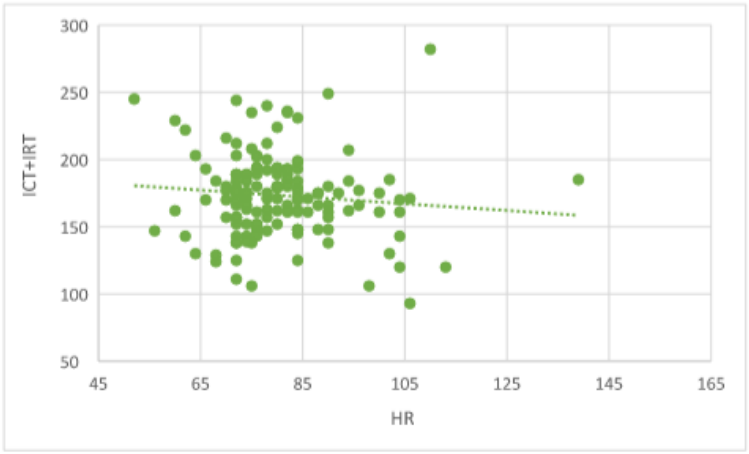

Figure 4 showing no statistically significant correlation between HR & ICT + IRT (p>0.05).

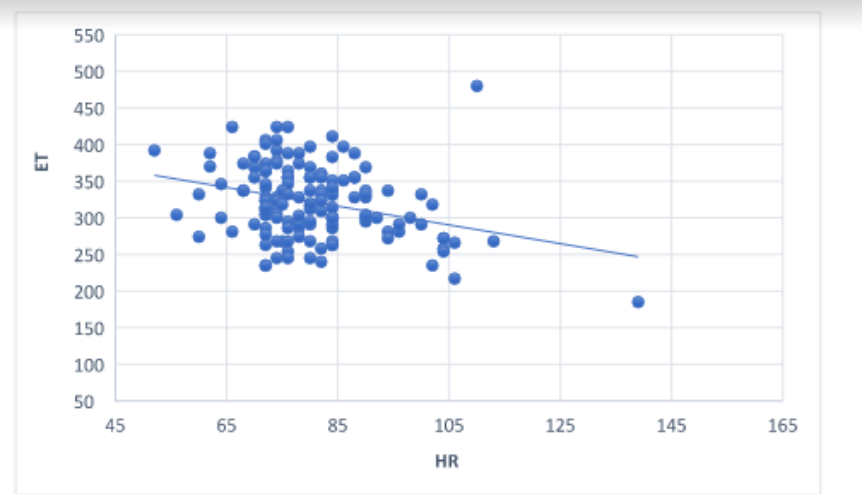

Figure 5: Correlation between HR & ET of the study population (n=500)

Figure 5 showing statistically significant correlation between HR & ET ($p<0.05$).

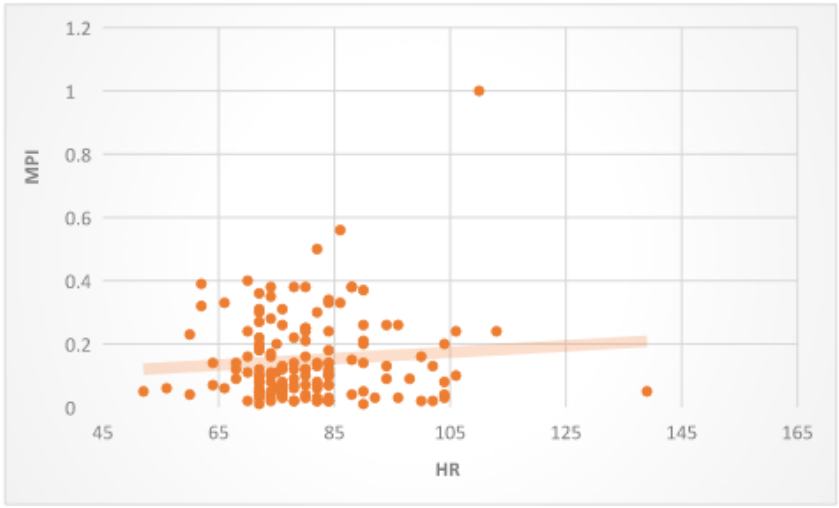

Figure 6: Correlation between MPI & HR of the study population (n=500)

Figure 6 showing no statistically significant correlation between MPI & HR ($p>0.05$).

IV. Discussion

Left Ventricular MPI (Tei index), is formulated as a parameter which can assess both systolic and diastolic function to express them as a single value. It is widely perceived as one parameter which is less often affected by the loading conditions[22,24]. LVEF measurement has provided valuable prognostic information regarding clinical outcome[25].

Global left ventricular performance is a function of both ventricular function & ejection. Numerous parameters are used to assess systolic or diastolic function till now. Since diastolic dysfunction is an integral part of systolic dysfunction [26, 27]a measure of both combinedly may better reflect 'global' function rather assessing them isolatedly. In this this, we tried to assess global cardiac function which incorporates factors related to both systolic & diastolic function.

Earlier studies showed isovolumic contraction time (ICT) & isovolumic relaxation time (IRT) reflect systolic & diastolic function of heart respectively [28-30]. They correspond with the active ventricular contraction & early relaxation [31]. Although individual measurement of ICT & IRT were required but MPI can be calculated from two easily measured Doppler time intervals (mitral closure-to-opening interval and ejection time.

In case of, patients with mitral regurgitation ICT & IRT do not exist. In these cases, 'duration of mitral closure-to-aortic-opening' and 'duration of aortic-closure-to mitral opening' are more appropriate variables to be considered. However, for easy understanding in this study we used considered ICT & IRT.

The rationale of the utility of MPI in the left ventricular dysfunction lies in the fact that (ICT+IRT)/ET corresponds with the important periods of contraction & relaxation of cardiac cycle. Calcium transportation at the myocellular level regulates the different cellular mechanisms of ICT & IRT [31]. Active myocardial processes are used to be suppressed in congestive heart failure and result in prolongation of active contraction & relaxation. Active contraction is reflected by an increase in ICT [33]. On the other hand, prolonged relaxation is initially associated with an increase in IRT but progressively worsening degree of ventricular dysfunction will influence this factor due to the involvement of other factors like left atrial pressure and the degree of mitral regurgitation [34]. Although due to the different factors, the present study proved that the sum of ICT & IRT proportionately increased as the left ventricular function depressed [35-37]. Ejection time (ET) was shorter in patients with severe left ventricular dysfunction compared to mild dysfunction & normals. Thus, with worsening left ventricular dysfunction (ICT+IRT)/ET increases disproportionately to any change of individual components.

Ejection fraction (EF) is the most commonly used index for the assessment of systolic function. It has served consistently as a good indicator of cardiovascular outcome and thus has great clinical relevance [38]. However, EF may not hold the true reflection of function in absence of normal shaped ventricles [39]. The adjunctive use of MPI may potentially provide useful support in these circumstances.

Use of EF alone may erroneously assess the contractility and thus function in patients with mitral regurgitation [40]. This limitation can be overcome by using MPI in adjunction with EF for the assessment of global function.

V. Conclusion

The study team concluded that myocardial performance index (MPI) is an adjunctive index combining both systolic and diastolic function parameters. The research team also appreciate its use to assess both systolic and diastolic myocardial function in patients with primary myocardial systolic dysfunction. We also welcome further study to clarify the utility of MPI in other patient populations and in the determination of cardiovascular outcome and prognosis.

Limitations of the study

The study team acknowledged several limitations during this study. These are:

- The study population was small.
- The patients from two centers were enrolled during the study. Incorporation of more centers can reflect more to the adult population of Bangladesh & thus the novelty of the study.
- As LVEF is load dependant variable, there was no correlation found between EF with other load dependant parameters like heart rate, blood pressure etc. However, further study is necessary to clarify the effect of loading conditions on MPI.
- MPI was measured only in normal subjects and primarily in patients with systolic dysfunction.
- In the presence of significant valvular heart disease & secondary myocardial dysfunction, Doppler time intervals may be influenced by abnormal haemodynamics related to abnormal valvular function.
- The result of this study may not be used in reference in the patients with congestive heart failure from primary diastolic dysfunction such as hypertrophic & restrictive cardiomyopathies.
- Last but not the least mitral flow may be significantly affected by atrioventricular block and atrial flutter. So, further study will be required to clarify the effect of arrhythmias on MPI.

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