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Echocardiographic assessment of right ventricular functions in patients with dilated cardiomyopathy: Strain imaging study

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Abstract:

Right ventricular (RV) dysfunction and dilatation are correlated to limited exercise capacity and poor outcome, dilated cardiomyopathy and ischemic heart disease can both lead to RV dysfunction. The aimed to evaluate RV function in patients with heart failure & comparison between idiopathic dilated cardiomyopathy versus ischemic dilated cardiomyopathy using strain imaging echocardiography.

The study included 50 patients with impaired left ventricular systolic function with EF% less than 40% and 15 healthy subjects with no history of medical or cardiac disease served as a control group. Patients were classified into ischemic cardiomyopathy (ICM) and dilated cardiomyopathy (DCM). Full history, clinical examination, ECG, full conventional echocardiography and assessment of LV & RV mechanics using speckle tracking imaging was done.

Results showed impairment of systolic strain values in both ICM & DCM groups compared to control group and a highly significant difference between both groups regarding global peak systolic longitudinal strain being impaired in DCM more than ICM group.

The difference regarding cumulative systolic strain rate between DCM & ICM groups was highly significant being more impaired in DCM than ICM group.

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Also, the difference regarding cumulative early and late diastolic strain rate between DCM& ICM groups was highly significant being impaired in DCM group than ICM group.

Our study showed that RV dysfunction is a prominent feature & an independent determinant of outcomes in patients with HFrEF. 2D strain imaging by STE seems to be a reliable quantification tool for assessment of RV function and for better discrimination between ICM &DCM patients.

Keywords: Cardiomyopathy, Right ventricle, Strain imaging.

Introduction

The role of the RV in the prognosis of many cardiac diseases, such as congestive heart failure, arrhythmia and sudden cardiac death is increasingly recognized (1).

Right ventricular (RV) dysfunction and dilatation are both correlated to limited exercise capacity and poor outcome, dilated cardiomyopathy (DCM) and ischemic heart disease (IHD) can both lead to RV dysfunction. Comparison between the two entities with respect to RV size and function may help to better understand the underlying pathophysiology of RV dysfunction (2-4).

2D strain imaging by STE seems to be a reliable quantification tool for assessment of RV function and for better discrimination between ICM &DCM patients. (5).

The aim of the study was to evaluate the RV function in patients with idiopathic dilated cardiomyopathy versus ischemic dilated cardiomyopathy using strain imaging echocardiography.

Methods

This was a prospective observational study conducted in Cardiology department, Menoufia University during the period from June 2016 to December 2019 on 50 subjects with impaired left ventricular systolic function with EF less than 40% and 15 healthy subjects served as a control group.

Patients were enrolled in the study after obtaining their written informed consent, and approval of the local ethics committee of the hospital.

Patients were divided into two groups based on the presence or absence of coronary artery disease, which was diagnosed by coronary angiography into:

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ICM group: included 25 patients with dilated cardiomyopathy with evidence of coronary artery disease.

DCM group: included 25 patients with idiopathic dilated cardiomyopathy with evidence of normal coronary arteries.

Control group: included 15 age & sex matched healthy subjects with no history of any chronic or cardiac disease with normal ECG & echocardiography findings.

Exclusion criteria:

Patients with Impaired renal function or haemodialysis, decompensated heart failure, recent ACS ,uncontrolled HTN ,atrial fibrillation , significant ventricular arrhythmia, moderate to severe tricuspid regurge , right bundle branch block and right ventricular pacing were excluded from the study.

All patients were subjected to detailed history, including CAD risk factors, physical examination, Electrocardiography (ECG) and laboratory investigations included, complete blood picture, liver and kidney function.

Echocardiographic images were obtained in the parasternal long-axis and short-axis and apical two-chamber and four-chamber views using standard transducer positions. Vivid 9, General Electric Healthcare (GE Vingmed, Norway) equipped with a harmonic M5S variable frequency (1.7 - 4 MHz) phased-array transducer was used. LV dimensions and wall thickness, EF, and left atrial diameter and volume were measured in accordance with the recommendations of the American Society of Echocardiography (6).

Peak early (E) and late (A) transmitral filling velocities were measured from mitral inflow velocities. Early diastolic (e') velocity was obtained by placing a tissue Doppler sample volume at the septal and lateral mitral annulus in the apical four-chamber view, and the mean value was obtained. The E/e' ratio was also calculated. Assessment of right ventricular systolic function by Tricuspid annular plane systolic excursion (TAPSE) was done.

2D strain analysis was performed offline using the Echopac software (General Electric version 1.8.1.X-Vingmed). All strain images were obtained at a frame rate of 59 - 82 frame/s. Three consecutive cardiac cycles were acquired at end expiration breath holding and digitally stored on a hard disk for off-line analysis. In order to measure the timing of cardiac events, LV inflow (mitral) and outflow (aortic) velocities were

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recorded using Pulsed wave Doppler. Longitudinal strain and strain rate were assessed in the 6 LV walls and the software algorithm automatically segmented the LV into an equidistant segment model in a ‘‘bull’s eye’’ plot and each segment was individually analyzed.

Peak longitudinal systolic strain (εsys), peak systolic strain rate (SRs), peak early diastolic strain rate (SRe), and peak late diastolic strain rate (SRa) in the basal, mid and apical segment of the RV free wall and also in the basal, mid, and apical segments of the septal, lateral, anterior, and inferior walls of the LV were measured. The measured values averaged to calculate global longitudinal deformation of the LV and RV free wall and used for comparison between the studied groups.

Coronary angiography was performed using multiple projections to differentiate between patients with CAD and patients with normal coronary arteries, Angiographic CAD was defined as ≥50% luminal diameter stenosis of at least one major epicardial coronary artery.

Statistical Analysis

All data were collected, tabulated and statistically analyzed using SPSS, (i.e. statistical package for social sciences) program for statistical analysis, (version 20; Inc., Chicago. IL). Qualitative variables as gender, smoking, hypertension, diabetes and family history were described in frequencies. Continuous data as age, total Cholesterol , LV parameters and RV TAPSE, Longitudimal strain was described as mean and SD (standard deviation). Chi-square test was used for discovering relationship between two categorical variables.

The one-way analysis of variance (ANOVA) was used to determine whether there were any statistically significant differences between the means of two or more independent (unrelated) groups. Post hoc range tests and pair wise multiple comparisons can determine which means differ.

Pearson's correlation coefficient measured the strength and direction of association between two continuous variables linear regression was used when we want to predict the value of a variable based on the value of another variable.

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Results were represented in tables. The level of significance was considered statistically significant if (P-value is < 0.05) and was high statistically signification if (P-value is < 0.001), While (P-value > 0.05) was considered non-significant.

Results

The study populations were classified into three groups:

ICM group: included 25 patients with mean age (55.04±7.21) with dilated cardiomyopathy with evidence of coronary artery disease.

DCM group: included 25 patients with mean age (51.84±12.00) with idiopathic dilated cardiomyopathy with evidence of normal coronary arteries.

Control group: included 15 age & sex matched healthy subjects with mean age (52.40±7.63) with no history of any chronic or cardiac disease with normal ECG & echocardiography findings as control group.

Demographic data:

The study included 50 patients, 25 male patients and 25 female patients. 22 patients were smokers, 35 were hypertensives and 36 were diabetics. There were no statistical significant differences among the groups regarding demographic data. Table (1)

Conventional echocardiography:

Left ventricular assessment:

Regarding conventional echocardiography parameters the study results showed, LVED, LVES and LA were significantly higher in ICM & DCM groups compared to control group (P-value <0.001), while EF% and FS%, were significantly lower in both patients groups than the control group (P-value <0.001). Furthermore, E/e' ratio was significantly higher in patients groups compared to the control group (P-value <0.001). table (2)

Right Ventricular Assessment

Comparison between the study groups according to TAPSE, showed a highly significant difference (P-value <0.001) which was impaired in both ICM & DCM groups than than control group. Meanwhile, comparison between ICM & DCM groups showed non significant difference with (P-value >0.05).

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Also, the difference between the three groups was highly significant as regard to PAP, TR velocity, and also between the ICM & DCM with parameters being higher in DCM than ICM group (P-value <0.001).

Comparison according to Tricuspid annular Tissue Doppler imaging (TDI) parameters showed a statistically highly significant difference between the three groups as well as between ICM & DCM groups as regard to S' wave(P-value < 0.001) and was impaired in DCM than ICM group, while the difference was insignificant regarding The E' wave (P-value > 0.05) Table (2) .

Srain Imaging

Left ventricular strain:

Left ventricular Peak Systolic strain

There was a statistically high significant difference between the study groups with lower values of cumulative longitudinal peak systolic strain of the inferior, anterior, lateral, septal, posterior, anteroseptal wall as well as lower average global LV strain in both patients groups than the control group (P-value < 0.001).

Similarly, there was a statistically highly significant difference between DCM & ICM groups (P-value <0.001) with low values of cumulative peak longitudinal systolic strain of each wall and lower average global LV strain in DCM group than ICM group. Table (3)

Peak Systolic strain rate; (SRs s-1)

The cumulative peak systolic strain rate of the inferior, anterior, lateral, septal, posterior, anteroseptal wall as well as the global LV systolic strain rate was significantly lower in both ICM & DCM groups in comparison to control group (P-value <0.001) while there was no significant difference between ICM & DCM groups. table (3)

Right ventricular strain:

Right ventricular systolic strain (Esys %).

Comparison between the three groups as regard peak longitudinal systolic strain demonstrated highly significant difference with (P-value <0.001).

Also, a highly significant difference between ICM & DCM groups as regard The Peak systolic longitudinal strain at the level basal, mid & apical segment (P-value < 0.001)

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with impairment of peak longitudinal systolic strain values in DCM more than ICM group. Table (4)

Right ventricular systolic strain rate:

Peak Systolic strain rate (SRs s-1)

There was a statistically highly significant difference was between the three groups regarding The Peak Systolic strain rate of RV free wall at basal, mid & apical segment as well as the cumulative systolic strain rate (P-value < 0.05)

Comparison between ICM & DCM groups showed a highly significant difference regarding The Peak systolic strain rate at basal segment (P-value <0.001) while there was No significant difference at mid and apical levels (P-value >0.05).

Also, the difference regarding cumulative systolic strain rate between DCM& ICM groups was highly significant (P-value <0.001) with the values being impaired in DCM group than ICM. Table (4)

Early Diastolic Strain Rate (SRes-1)

A statistically highly significant difference between the study groups regarding the early diastolic strain rate of RV free wall at basal, mid & apical segment as well as the cumulative systolic strain rate (P-value < 0.05)

The difference between ICM & DCM groups was highly significant regarding The early diastolic strain rate at basal segment (P-value <0.001) while there was a significant difference at mid and apical levels with (P-value >0.05).

Also, the difference regarding cumulative early diastolic strain rate between DCM& ICM groups was highly significant with (P-value <0.001) being impaired in DCM group than ICM. Table (4)

Late Diastolic Strain Rate (SRas-1)

A statistically highly significant difference between study groups regarding The late diastolic strain rate of RV free wall at basal, mid & apical segment as well as the cumulative late diastolic strain rate (P-value < 0.001)

The difference between ICM & DCM groups was significant regarding. The late diastolic strain rate at basal segment (P-value <0.05) while it was non-significant at mid and apical levels with (P-value>0.05).

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Regarding cumulative late diastolic strain rate between DCM& ICM groups was the difference was highly significant with (P-value <0.001) being impaired in DCM than ICM group Table (4)

Correlations

The average RV global longitudinal strain showed significant negative correlation with TAPSE, TR velocity and PAP (P-value <0.001) while there was no significant correlation was found between all these parameters and the average RV systolic strain rate (P-value >0.05). Figure (1)

There was significant negative correlation between the average systolic velocity (S') of the tricuspid annulus by DTI and both the average RV systolic strain & strain rate. (P-value <0.001). Figure (1)

Receiver operating characteristic (ROC) curves and optimal cut offs of RV peak systolic strain and strain rate

To explore the cutoff point that discriminate RV dysfunction in ICM & DCM we constructed ROC curves for global RV strain & strain rate in the study populations.

For average global RV strain, a value >-12.53% could discriminate between ICM and DCM with 80% sensitivity and 92% specificity, with parameters below this value refer to the patient with idiopathic DCM. For the average RV global SRe, a cutoff >-1.16 value had 92% sensitivity and 88% specificity for differentiation between ICM and DCM, with parameters below this value refer to the patient with idiopathic DCM. figure (2)

Discussion

The effect of left ventricular function on the outcome of heart failure has been well documented. Right ventricular (RV) performance is connected to LV dysfunction in multiple ways (shared fibers and septal wall, increased LV filling pressures, ventricular interdependence). As a result, the right ventricle (RV) is pivotal in maintaining hemodynamic stability and an adequate cardiac output. Many studies point to a crucial role for RV systolic function in the course of several cardiovascular diseases. (7-10)

Evaluation of RV performance remains challenging in routine practice and, as a result, RV function has long been neglected. Imaging studies used to assess RV systolic function as echocardiography, angiography, radionuclide ventriculography, and

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magnetic resonance imaging. Of these, echocardiography is the most readily available and the most widely used in everyday clinical practice. (11,12)

2D imaging of myocardial deformation, or strain, was found useful for assessing left ventricular function. (13) Also, it is easily feasible on echocardiography systems and has been shown to reliably reflect RV function. Strain imaging is a method that allows the non-invasive assessment of myocardial contractility. Compared to tissue Doppler-based strain imaging, two-dimensional (2D) strain imaging by speckle tracking shows technical advantages such as angle-independent measurements and low frame rate image acquisition. (14)

This study included 50 patients with cardiomyopathy & left ventricular EF less than 40%. Patients subjected to study were classified according to the presence or absence of coronary artery disease into ICM (patients with ischemic dilated cardiomyopathy) and DCM (patient with idiopathic dilated cardiomyopathy).

Assessment of RV function by TAPSE showed impairment of the value of TAPSE in both groups (DCM) & (ICM) in comparison to control group. This was concordant with Ghio et al. (15) which showed that a reduced value of TAPSE is associated with poor prognosis in patients with HF, as confirmed in another study since it was attested how a value of TAPSE above 12.5 mm might help the identification of HF patients with a better event-free survival. Also, TAPSE is extremely easy to be obtained, is poorly dependent on image quality, and is highly reproducible .Furthermore its good correlation with RVEF is assessed with cardiac magnetic resonance (CMR) (15).

TDI allows the evaluation of longitudinal RV function during systole in terms of tissue velocities. The normal TDI profile is composed by a positive systolic myocardial velocity (S′) and two diastolic myocardial velocities, early-diastolic (E′) and late-diastolic (A′). S′ emerged as a more precise index of systolic function, strictly related to RV EF measured by CMR. An S′ value < 9.5 cm/s identifies RV dysfunction (16).

According to Donal E, et al. (17).S′ TDI-derived parameters represented.an added tool in stratifying the risk of patients with HF; in particular, the presence of S′-wave > 9 cm/s (so similar to the lower normal limit) was associated with a free-event survival. This also was concordant with the result of this study which showed significant impairment of S' systolic wave of TDI in both ischemic and dilated cardiomyopathy groups in comparison to control group. (17)

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Using speckle tracking in studying right ventricular function, results showed RV systolic & diastolic dysfunction at both global & regional levels in patients with dilated cardiomyopathy in both ischemic and idiopathic groups. This was supported by a study by Soulef Guendouz et al. (18) which was performed at 43 controls and 118 stable patients with heart failure & reduced ejection fraction for assessment of right ventricular systolic function in patients with chronic heart failure. This study concluded that RV-2D strain reliably reflected RV systolic function, and can be superior to other systolic RV echocardiographic variables, also is considered a strong independent predictor of severe adverse events in patients with CHF. (18)

Also, a significant difference between the DCM & ICM groups with impairment of peak longitudinal RV systolic strain values in DCM group more than in ICM group, this was concordant with Antonello D'andrea et al. (19) a study done for assessment of right ventricular function in patients with idiopathic and ischemic dilated cardiomyopathy& for studying the effects of cardiac resynchronization therapy. This study showed that RV strain values at baseline and after CRT are more impaired in DCM compared with ICM patients. So, 2-D strain represents a promising noninvasive technique to assess RV myocardial function in patients with DCM. (19)

However, this was against a study by Ewelina Kowalczyk et al. (20) which aimed to differentiate between patients with ischemic and non-ischemic etiology of reduced left ventricular ejection fraction using 2D speckle tracking echocardiography. Results of this study showed that both systolic longitudinal strain and early systolic strain rate didn't show significant difference between the ICM & DCM groups, and the difference was significant only as regard to early diastolic strain rate being impaired in DCM group than ICM group. Also, this was matched with our results regarding RV strain rate which showed significant difference between the two groups including both segmental and cumulative values regarding early diastolic strain rate, meanwhile, both systolic and late diastolic strain rate showed significant difference al basal & cumulative levels only, and that indicate that early diastolic strain rate is the most reliable parameter in differentiation between ICM & DCM. (20)

Correlation done between the values of the RV global peak systolic longitudinal strain & RV global strain rate was done with TAPSE, showed a negative significant difference

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with both parameters. Also, TAPSE showed non-significant difference in comparing between ICM & DCM groups by conventional 2D echocardiography.

This was found to be concordant with a study by Erberto Carluccio et al.,(21) Which was performed on a total of 200 patients with HF with reduced ejection fraction & preserved tricuspid annular plane systolic excursion (>16 mm). RV function assessment was done using speckle-tracking echocardiography to measure peak RV strain for studying prognostic value of right ventricular dysfunction in heart failure with reduced ejection fraction & the superiority of longitudinal strain over TAPSE, This study showed that among patients with chronic HFrEF& preserved TAPSE, there still is a proportion of patients in whom RV function may be impaired when assessed by strain analysis, also STE has the ability to discriminate between various myocardial segmental deformation. (21)

Again, this was concordant with a study by Sciaccaluga1et al. (22) This study summarized the role of standard and advanced echocardiographic techniques together with CMR in the evaluation of the RV function in HF, and concluded that TAPSE had limitations as it is angle-dependent and explore only a small basal portion of RV free wall, so this might lead to an underestimation or overestimation of global RV systolic function, especially in HF patients. For these reasons, it is suggested to integrate TAPSE with other indexes in each echocardiographic report. (22)

Conclusion

Two dimensional strain imaging by STE seems to be a reliable quantification tool for assessment or RV function and for better discrimination between ICM & DCM patients & should be implemented in analysis of longitudinal strain in patients with HFrEF, to improve identification of patients who are at risk for adverse events.

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Table (1): Comparison between the study groups regarding demographic data and risk factors

		Groups						ANOVA	
		Control N=15		ICM N=25		DCM N=25		F	P-value
Age	**Mean ±SD**	52.40±7.63		55.04±7.21		51.84±12.00		0.789	0.459
Chi-Square		**N**	**%**	**N**	**%**	**N**	**%**	**X^2**	**P-value**
Gender	**Female**	7	46.67	12	48.00	13	52.00	0.131	0.936
	Male	8	53.33	13	52.00	12	48.00		
Smoking	**Non smoker**	10	66.67	16	64.00	17	68.00	0.092	0.955
	Smoker	5	33.33	9	36.00	8	32.00		
HTN	**Negative**	7	46.67	8	32.00	15	60.00	3.945	0.139
	Positive	8	53.33	17	68.00	10	40.00		
DM	**Negative**	9	60.00	7	28.00	13	52.00	4.782	0.092
	Positive	6	40.00	18	72.00	12	48.00		

P value > 0.05= insignificant, P value <0.05 *Significant P < 0.001 = highly significant.

, X2: Chi-square test

ICM, ischemic cardiomyopathy DCM, Dilated cardiomyopathy

HTN, Hypertension DM, Diabetes mellitus

Table (2): Comparison between the study groups by conventional echocardiography.

LV	Control N=15			ICM N=25			DCM N=25			ANOVA		TUKEY'S Test		
	Mean	**±**	**SD**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	**F**	**P-value**	**P1**	**P2**	**P3**
IVS (cm)	0.73	±	0.16	0.97	±	0.25	0.80	±	0.21	6.649	0.002*	0.003*	0.525	0.026*
LVPW (cm)	0.78	±	0.17	1.03	±	0.28	0.88	±	0.25	5.340	0.007*	0.007*	0.400	0.090
LVED (cm)	4.57	±	0.32	6.22	±	0.54	6.37	±	0.61	60.550	<0.001*	<0.001*	<0.001*	0.574
LVESD (cm)	2.91	±	0.32	4.90	±	0.68	5.28	±	0.61	82.081	<0.001*	<0.001*	<0.001*	0.069

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LA (cm)	2.82	±	0.37	3.92	±	0.47	4.43	±	0.65	43.587	<0.001*	<0.001*	<0.001*	0.003*
Ao (cm)	2.61	±	0.26	2.87	±	0.27	2.92	±	0.50	3.288	0.044*	0.095	0.043*	0.910
EF%	62.20	±	3.03	33.48	±	6.78	31.16	±	7.56	123.535	<0.001*	<0.001*	<0.001*	0.420
FS%	40.73	±	2.31	16.80	±	3.83	15.88	±	3.77	277.716	<0.001*	<0.001*	<0.001*	0.627
E m/s	9.13	±	0.42	5.92	±	0.41	6.10	±	0.32	393.443	<0.001*	<0.001*	<0.001*	0.239
A m/s	6.73	±	0.37	3.43	±	0.38	3.68	±	0.33	453.986	<0.001*	<0.001*	<0.001*	0.042*
E/e'	1.35	±	0.11	8.03	±	1.19	7.36	±	0.80	292.585	<0.001*	<0.001*	<0.001*	0.029*
RV														
TAPSE (cm)	2.60	±	0.19	1.71	±	0.20	1.72	±	0.24	98.871	<0.001*	<0.001*	<0.001*	0.998
PAP	23.33	±	0.98	28.20	±	2.48	33.04	±	5.24	34.219	<0.001*	<0.001*	<0.001*	<0.001*
TR velocity	1.60	±	0.16	2.50	±	0.39	2.10	±	0.32	37.073	<0.001*	<0.001*	<0.001*	<0.001*
S m/s	13.45	±	0.85	9.24	±	1.89	4.95	±	0.83	192.617	<0.001*	<0.001*	<0.001*	<0.001*
E' m/s	5.86	±	0.31	5.96	±	0.74	5.72	±	0.86	0.678	0.511	0.912	0.823	0.481

FS%: fractional shortening; EF%: Ejection fraction; PWD: LV posterior wall dimension in diastole; LVESD: LV end systolic dimension; LVEDD: LV end diastolic dimension in diastole; IVSD: Interventricular septum dimension in diastole AO: Aorta; LA: left atrium.

P1=between control&ICM, P2= between control&DCM, P3 = between ICM&DCM

P value > 0.05= insignificant, P< 0.05 = significant, P < 0.001 = highly significant.

TAPSE: Tricuspid annular plane systolic excursion S m/s: St velocities & E' m/s:Et peak velocities,;TR: Tricuspid Regurge; PAP:pulmonary artery pressure

P1=between control&ICM, P2= between control&DCM, P3 = between ICM&DCM

P value > 0.05= insignificant, P< 0.05 = significant, P < 0.001 = highly significant.

Table (3) comparison between study groups regarding left ventricular strain & strain rate.

LV strain C	**Control**			**ICM**			**DCM**			**ANOVA**		**TUKEY'S Test**		
	Mean	**±**	**SD**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	**F**	**P-value**	**P1**	**P2**	**P3**
Inferior	-24.55	±	1.43	-10.76	±	5.42	-4.07	±	1.07	160.881	<0.001*	<0.001*	<0.001*	<0.001*
Anterior	-20.33	±	2.90	-9.66	±	4.88	-5.18	±	1.26	92.666	<0.001*	<0.001*	<0.001*	<0.001*
Lateral	-18.45	±	0.98	-9.71	±	4.53	-5.25	±	1.13	94.528	<0.001*	<0.001*	<0.001*	<0.001*
Septal	-22.67	±	1.59	-10.57	±	4.17	-4.52	±	1.41	191.935	<0.001*	<0.001*	<0.001*	<0.001*
Post	-17.90	±	0.65	-9.37	±	3.97	-4.57	±	0.99	126.796	<0.001*	<0.001*	<0.001*	<0.001*
Anteroseptal	-23.49	±	1.84	-9.83	±	5.18	-4.29	±	0.95	152.107	<0.001*	<0.001*	<0.001*	<0.001*

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Global	-21.09	±	0.63	-9.98	±	1.04	-4.64	±	0.58	1982.272	<0.001*	<0.001*	<0.001*	<0.001*

LV sys strain rate (cumulative)	**Control N=15**			**ICM N=25**			**DCM N=25**			**ANOVA**		**TUKEY'S Test**		
	Mean	**±**	**SD**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	**F**	**P-value**	**P1**	**P2**	**P3**
Inferior	-1.96	±	0.21	-1.33	±	0.56	-1.20	±	0.30	17.368	<0.001*	<0.001*	<0.001*	0.503
Anterior	-1.82	±	0.27	-1.23	±	0.58	-1.16	±	0.28	12.947	<0.001*	<0.001*	<0.001*	0.815
Lateral	-1.94	±	0.16	-1.33	±	0.55	-1.09	±	0.22	23.876	<0.001*	<0.001*	<0.001*	0.074
Septal	-1.95	±	0.11	-1.21	±	0.69	-1.07	±	0.24	18.791	<0.001*	<0.001*	<0.001*	0.520
Post	-1.85	±	0.09	-1.14	±	0.67	-1.08	±	0.28	15.467	<0.001*	<0.001*	<0.001*	0.907
Anteroseptall	-1.96	±	0.28	-1.20	±	0.51	-1.06	±	0.35	24.661	<0.001*	<0.001*	<0.001*	0.428
Global	-1.91	±	0.15	-1.25	±	0.25	-1.11	±	0.23	63.093	<0.001*	<0.001*	<0.001*	0.087

P1=between control&ICM, P2= between control&DCM, P3 = between ICM&DCM

X2: Chi-square test

P value > 0.05= insignificant, P value <0.05 *Significant P < 0.001 = highly significant.

ICM (ischemic cardiomyopathy) DCM (Dilated cardiomyopathy)

Table (4) comparison between study groups regarding right ventricular strain & strain rate.

RV strain	**Control N=15**			**ICM N=25**			**DCM N=25**			**ANOVA**		**TUKEY'S Test**		
	Mean	**±**	**SD**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	**F**	**P-value**	**P1**	**P2**	**P3**
Basal	-28.54	±	2.44	-16.24	±	2.81	-10.79	±	3.13	181.310	<0.001*	<0.001*	<0.001*	<0.001*
Mid	-26.95	±	2.37	-14.84	±	3.87	-10.17	±	3.00	127.161	<0.001*	<0.001*	<0.001*	<0.001*
Apical	-25.01	±	2.24	-15.52	±	4.04	-10.31	±	3.18	89.391	<0.001*	<0.001*	<0.001*	<0.001*
Global	-26.83	±	1.84	-15.54	±	2.43	-10.42	±	2.58	225.880	<0.001*	<0.001*	<0.001*	<0.001*

RV strain rate S	**Control N=15**			**ICM N=25**			**DCM N=25**			**ANOVA**		**TUKEY'S Test**		
	Mean	**±**	**SD**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	**F**	**P-value**	**P1**	**P2**	**P3**
Basal	-3.51	±	0.74	-1.56	±	0.42	-0.89	±	0.26	151.750	<0.001*	<0.001*	<0.001*	<0.001*
Mid	-6.90	±	1.85	-1.52	±	0.45	-0.99	±	0.23	213.218	<0.001*	<0.001*	<0.001*	0.117
Apical	-2.31	±	0.67	-1.27	±	0.40	-1.04	±	0.23	43.827	<0.001*	<0.001*	<0.001*	0.147
Cumulative	-4.24	±	0.72	-1.45	±	0.24	-0.97	±	0.21	346.802	<0.001*	<0.001*	<0.001*	<0.001*

RV strain rate E	**Control N=15**			**ICM N=25**			**DCM N=25**			**ANOVA**		**TUKEY'S Test**		
	Mean	**±**	**SD**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	**F**	**P-value**	**P1**	**P2**	**P3**
Basal	2.96	±	0.68	1.39	±	0.42	0.88	±	0.28	101.427	<0.001*	<0.001*	<0.001*	0.001*
Mid	6.59	±	1.50	1.53	±	0.42	0.91	±	0.23	281.185	<0.001*	<0.001*	<0.001*	0.017*
Apical	2.01	±	0.57	1.35	±	0.52	0.98	±	0.22	25.091	<0.001*	<0.001*	<0.001*	0.014*
Cumulative	3.85	±	0.73	1.42	±	0.24	0.93	±	0.21	269.294	<0.001*	<0.001*	<0.001*	<0.001*

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RV strain rate A	Control N=15			ICM N=25			DCM N=25			ANOVA		TUKEY'S Test		
	Mean	±	SD	Mean	±	SD	Mean	±	SD	F	P-value	P1	P2	P3
Basal	3.40	±	0.57	1.29	±	0.49	0.88	±	0.25	170.579	<0.001*	<0.001*	<0.001*	0.004*
Mid	6.58	±	2.14	1.21	±	0.44	0.86	±	0.24	157.892	<0.001*	<0.001*	<0.001*	0.469
Apical	2.20	±	0.59	1.15	±	0.42	0.92	±	0.31	43.680	<0.001*	<0.001*	<0.001*	0.155
Cumulative	4.06	±	0.71	1.22	±	0.24	0.88	±	0.23	343.798	<0.001*	<0.001*	<0.001*	0.011*

P1=between control&ICM, P2= between control&DCM, P3 = between ICM&DCM

P value > 0.05= insignificant, P< 0.05 = significant, P < 0.001 = highly significant.

ICM (ischemic cardiomyopathy) DCM (Dilated cardiomyopathy)

Legend of figure

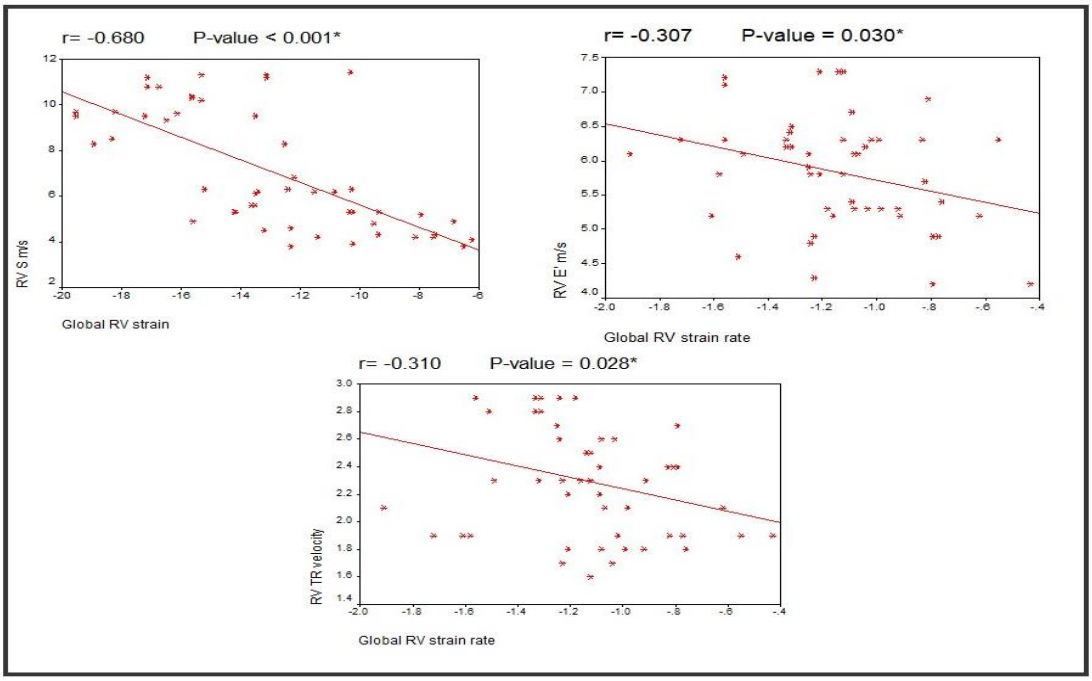

Figure (1): Correlation between RV strain & strain rate and different RV conventional echo parameters

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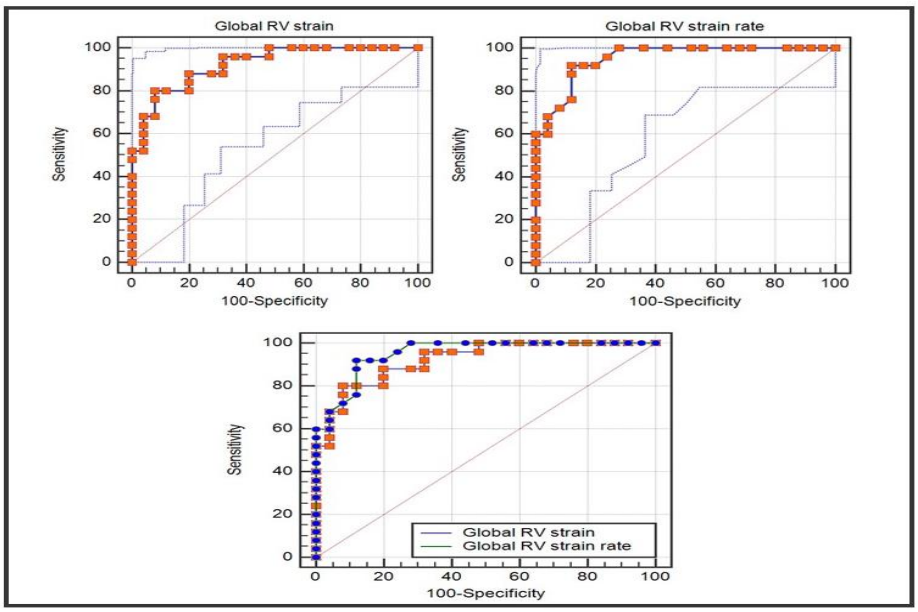

Figure (2): ROC curve between ICM & DCM groups as regard global strain & strain rate values