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Original Research Article

Real time 3D echocardiography for evaluation of systolic dyssynchrony index in patients with dilated cardiomyopathy and acute myocardial infarction

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ABSTRACT

Background: In recent years, real time 3D echocardiography (RT3DE), a novel and non-invasive method has catched the eyes of various cardiologists for evaluating ventricular dyssynchrony. The main aim of the present study was to establish applicability of RT3DE for the assessment of ventricular dyssynchrony in patients with dilated cardiomyopathy (DCMP) and acute myocardial infarction (AMI).
Methods: It was a hospital based observational and comparative study which included total 105 patients. Among all the patients, 35 with DCMP, 35 with AMI and 35 healthy patients were included. Various electrocardiographic, 2D and 3D echocardiography parameters were evaluated. Percentage ventricular systolic dyssynchrony index (SDI) was estimated using RT3DE to define ventricular dyssynchrony. The correlation of SDI with left ventricular ejection fraction (LVEF) and QRS duration of all patients was calculated using Pearson correlation co-efficient and regression equation.
Results: Age distribution among all three groups was non-significant with mean age 53.56±12.11 years. The RT3DE displayed significantly higher SDI (p=0.001) in DCMP group (16.67±5.81 %) followed by AMI group (8.6±2.2%) and control group (3.14±1.0%). The value of QRS duration was also higher (>140ms) in DCMP patients (142.40±34.71ms) and lower (>120ms) in AMI (108.85±20.67ms) and healthy patients (91.08±8.88ms). No significant correlation of SDI with LVEF among all three groups was observed.
Conclusions: The results added more practicality of RT3DE for estimation of ventricular dyssynchrony in patients with varied cardiac conditions and also displayed its utility as an appropriate guide for cardiac resynchronization therapy.

Keywords: Acute myocardial infarction, Dilated cardiomyopathy, Real time 3D echocardiography, Systolic dyssynchrony index, Ventricular dyssynchrony

INTRODUCTION

At present, cardiovascular diseases (CVD) are the major cause of death in India and CVD's pervasiveness is incessantly growing. Among all CVD, congestive heart failure (CHF) is one of the chief causes of mortality and more than 20% of CHF displayed conduction system diseases.[1-3] Hence, the evaluation of ventricular performance has been considered as an imperative facet for diagnosis, for estimation of prognosis of CHF as well as understanding the natural history of CVD. Various electrocardiographic (ECG) and echocardiographic parameters have been employed to determine the ventricular dyssynchrony and also to determine the need

of cardiac resynchronization therapy (CRT) in patient of CHF. The CRT embroils synchronized pacing of both ventricles which helps to restore the left ventricular synchrony and to improve mechanical function of the left ventricle.[4] From several years, ECG-QRS duration (>120ms) and left ventricular ejection fraction (LVEF ≤35%) assist as a chief indication for CRT. However, around 30% patients failed to response to CRT despite of wider QRS, which led to practice various echocardiographic parameters to define ventricular dyssynchrony and CRT.[5-8]

Several echocardiographic modalities such as M-mode, 2D-echocardiography with strain, strain-rate, tissue tracking techniques and tissue Doppler imaging; and real time 3D-echocardiography (RT3DE) have been used to assess ventricular systolic performance.[3,7,9,10] The use of RT3DE impart several advantages over other conventional modalities as it offers an accurate and quantitative means of computing the global and regional ventricular function from multiple observational planes and is not based on the geometric interference.[3,5] Numerous studies in literature have determined the use of ventricular dyssynchrony to guide the CRT for heart failure patients.[2,11-15]

The cardiac ventricular systolic dyssynchrony index (SDI) has been measured by RT3DE using 16/17 myocardial segment model to quantify the ventricular mechanical dyssynchrony.[16] The %SDI is the standard deviation of the mean end-systolic contraction time of each cardiac segment in comparison with the global end-systolic contraction. Here, the present study sought to establish feasibility of RT3DE for the assessment of ventricular dyssynchrony in varied cardiac abnormalities. It also compared ventricular dyssynchrony (analysed by RT3DE) with LVEF measurements and QRS duration (analysed with 2D and RT3D echocardiography) in healthy and in patients with acute myocardial infarction (AMI) and dilated cardiomyopathy (DCMP).

METHODS

It was a hospital based observational and comparative study conducted at a tertiary care centre in India. The study enrolled total 105 patients which was an amalgam of 35 patients with ST-segment elevated acute myocardial infarction (AMI), 35 patients with dilated cardiomyopathy (DCMP) and 35 patients with normal cardiac function as control group. The written consent was obtained from each patient before the commencement of the study.

The inclusion criteria of the study were: age ≥ 18 years; for study groups- patient with ST-segment elevated AMI and patients with DCMP of various etiologies; for control group-patients with normal 2D and 3D echocardiographic analysis, normal conventional Doppler and tissue Doppler; and normal 12 lead ECG; or healthy humans. The exclusion criteria were: technically inadequate quality of 2D and 3D echocardiogram, patients with irregularity of the heart rhythm and patients with atrial fibrillation.

The routine demographic, biochemical, clinical, ECG and echocardiographic characteristics were evaluated for all the patients in the study. The parameters estimated for 2D and 3D echocardiography were left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic volume (LVESV) and LVEF (Simpson's rule). Percentage left ventricular systolic dyssynchrony index (SDI) was estimated using RT3DE to define ventricular dyssynchrony. The 16-ventricular segment model was used for the analysis of left ventricular contractility. The left ventricular dyssynchrony index represents the variation of left ventricular volumes in relation to their temporal occurrence within the cardiac cycle, i.e. it represents the change of the global systolic volume into global diastolic volume from the temporal point of view. The %SDI delineates the standard deviation of the mean end-systolic contraction time of each cardiac segment in comparison to the global end-systolic contraction. 3D echocardiographic images were developed in the sequence of the 2D echocardiographic test. The images were obtained with the same echocardiographic equipment, using a matrix transducer with the patient in expiratory breath hold.

All statistical analysis was performed using Statistical Package for the Social Sciences (version 15; Chicago, IL, USA). The continuous variables were articulated as mean ± standard deviation (SD) and qualitative variables were expressed as frequency and percentage. Analysis of variance (ANOVA) test was performed to compare QRS duration, the 2D and 3D echocardiographic parameters (LVEF, LVESV, LVEDV and 3D echo-SDI) among DCMP, AMI and control group. The correlation of SDI with 2D and 3D EF among DCMP, AMI and control groups and; SDI with QRS duration of all patients was calculated using Pearson correlation co-efficient and regression equation.

RESULTS

The present study involved total 105 patients and among all 35 were healthy patients, 35 with AMI and 35 with DCMP. The details of age distribution and gender distribution among all three groups are outlined in Table 1. Age distribution among all three groups was non-significant with mean age 53.56±12.11 years. The study included 82 (78%) male patients without any significant difference among the groups.

Table 1 also comprehends the distribution and values of different parameters of ECG, 2D and 3D echocardiography among DCMP, AMI and control groups. The control group showed QRS duration of 91.08±8.88ms on surface ECG. In addition, echocardiography examinations were normal and ruled out valve disease or any other cardiomyopathy. The AMI

group showed QRS duration of 108.85±20.67ms with 5 left bundle branch block (LBBB) and 1 right bundle branch block (RBBB). The localization of the AMI was anterior in 22 patients and infero-posterior in 13 patients. The DCMP group showed QRS duration of 142.40±34.71ms with 15 LBBB and 6 RBBB. The incidences of LBBB and RBBB both were significantly higher in DCMP group compared to AMI.

Table 1: Demographic and cardiac function diagnostic parameters in all three groups.

Variables	DCMP	AMI	Control	P-value
Age	50.85±12.17	55.97±10.73	53.85±13.11	-
Male	29 (82.9%)	28 (80.0%)	25 (71.4%)	-
Parameters of ECG				
LBBB	15 (42.9%)	5 (14.3%)	0	-
RBBB	6 (17.1%)	1 (2.9%)	0	-
Normal	14 (40.0%)	29 (82.9%)	35 (100%)	-
QRS (ms)	142.40±34.71	108.85±20.67	91.08±8.88	0.001
Parameters of 2D Echocardiography				
EF (%)	26.88±5.87	35.62±4.92	62.65±2.82	0.001
ESV (ml)	110.08±27.67	69.60±9.55	40.97±5.84	0.001
EDV (ml)	149.40±32.57	107.67±12.23	110.10±14.36	0.001
Parameters of 3D Echocardiography				
EF (%)	23.51±5.23	33.00±5.38	64.08±3.40	0.001
ESV (ml)	117.78±29.34	74.07±10.60	39.50±5.37	0.001
EDV (ml)	152.36±32.76	110.44±11.92	110.39±13.63	0.001
SDI (%)	16.67±5.81	8.60±2.21	3.14±1.00	0.001

Table 2: Correlation of SDI with other variables.

Variables		DCMP	AMI	Control
3D EF	Pearson correlation	0.294	0.010	-0.030
	P-value	0.086	0.954	0.863
2D EF	Pearson correlation	0.302	0.016	-0.096
	P-value	0.078	0.929	0.584
QRS (among all n=105 patients)	Pearson correlation	0.67		
	P-value	0.0001		

There was a significant difference among three groups in terms of 3D echo variables like LVEF, LVEDV and LVESV. The patients with DCMP showed significantly larger LV volumes (LVESV: 117.78±29.34ml and LVEDV: 152.36±32.76ml) and lower EF (LVEF: 23.51±5.23%) compared to the patients with AMI (LVESV: 74.07±10.60ml; LVEDV: 110.44±11.92ml and LVEF: 33.00±5.38%) and healthy patients (LVESV: 39.50±5.37ml; LVEDV: 110.39±13.63ml and LVEF: 64.08±3.40%)

The RT3DE displayed significantly higher SDI (p=0.001) in DCMP group (16.67±5.81%) in comparison to AMI group (8.6±2.2%) and control group (3.14±1.0%). The cut-off value used to define LV mechanical dyssynchrony was defined arbitrarily as mean + 3SD of the SDI value found in the healthy population of the present study (SDI=6%).

No significant correlation of SDI with LVEF measured by 2D and 3D echocardiography among all three groups was observed.

While on other hand, a significant positive correlation was observed between SDI and QRS duration among all groups. A higher SDI was strongly and significantly associated with wider QRS duration. The correlation of SDI with 2D and 3D LVEF and QRS are specified in Table 2.

DISCUSSION

The CRT has been considered as highly beneficial therapy in patients with severe heart failure as it has significantly improved survival rate, quality of life, LVEF, oxygen consumption and exercise tolerance post-therapy.[4,17]

As per standard guidelines, electrocardiographic QRS duration (>120ms) has been used to define LV dyssynchrony but its use still remain controversial to predict response of CRT. Furthermore, various studies proved that several echocardiographic methods did not provide accurate detection of electromechanical ventricular dyssynchrony and also failed to select appropriate candidate for CRT.[7,9,10] Thus, there has been still lack of apt echocardiographic method for evaluation ventricular dyssynchrony and also a guide for CRT.[18] Nowadays, RT3DE, a unique and emerging imaging technique, has been in practice for precise assessment of ventricular performance and also to decide the need for resynchronization therapy for CHF patients.

In the present study, SDI was calculated using RT3DE for estimation of electromechanical ventricular dyssynchrony in three different group of patients (DCMP, AMI and healthy). The SDI value in this study represented different degrees of synchronicity with respect to different cardiac conditions. Various studies have been available in literature which demonstrated applicability of RT3DE for estimation of electromechanical dyssynchrony in different cardiac clinical settings.[5,19] It has been found in previous study that SDI assessed with RT3DE was significantly higher value in patients with DCMP (14.3±7.5%).[9] In similar to this, the present study also displayed significantly higher value of SDI in DCMP patients (16.67±5.81%) and also in AMI patients (8.60±2.21%) compared to healthy patients (3.14±1.00%). A meta-analysis of total 73 studies demonstrated 94% feasibility of RT3DE for the assessment of ventricular dyssynchrony and also stated that SDI provides good predictive response to CRT.[5]

Numerous studies in the literature demonstrated the negative correlation of SDI value measured using RT3DE with 2D and 3D LVEF i.e. lowered the LVEF higher the value of SDI.[3,9,20] In contrast to this, in the present study didn't showed significant correlation of SDI and both 2D and 3D LVEF in any group of patients (Table 2). Furthermore, the study by Tani T et al, reported a significant positive correlation between QRS width with SDI ($r = -0.41$, $p<0.0001$) which was homogenous with the results of the present study ($r = 0.67$, $p<0.0001$).[20] On contrary, the results of study by Kapetanakis et al revealed a weak relation of QRS with SDI.[2]

The values of LVEF, systolic and diastolic ventricular volumes obtained using 2D and 3D echocardiographies were varied from each other but the difference was statistically non-significant for all three groups. In this study, SDI cut-off value to delineate the ventricular dyssynchrony was 6% which was almost similar to the previous other studies.[9,13] All these results have added more value to the use of RT3DE for evaluation of ventricular dyssynchrony in patients with varied clinical cardiac conditions and also displayed its utility as an appropriate guide for CRT.

Despite technological advances, RT3DE still has limited applicability in patients with difficult acoustic windows. In our case, 10 patients were excluded from analysis due to bad quality images, which yields a feasibility rate around 90%. Another limitation that should be taken into account was the low frame rate of the acquired data which led to lack of reproducibility of the measurements and could be included in the future studies. We did not demonstrate a cut-off value in patients with dilated cardiomyopathy from which mid-long-term response to CRT could be predicted. Indeed, this was not the aim of the present study so in future studies such cases could be included. The study should be broadened to include a greater number of patients with ventricular dysfunction in different clinical situations, such as individuals with atrial fibrillation and patients with narrow QRS with evidence of electromechanical dyssynchrony.

CONCLUSION

The RT3DE can be considered as an evolving non-invasive method for the quantitative assessment of global as well as segmental/regional (even in most delayed myocardial area) ventricular dyssynchrony in patient with severe clinical cardiac conditions and also helps to optimise the use CRT. 3D-echo SDI can be considered a novel echo parameter to define ventricular dyssynchrony as no other echo parameters defining dyssynchrony has been approved so far in any guidelines.

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