Original article

Early prediction of left ventricular systolic dysfunction in patients of asymptomatic chronic severe rheumatic mitral regurgitation using tissue Doppler and strain rate imaging

Manish Gunjan¹, Sumod Kurien^{2*}, S. Tyagi³

¹Senior Resident, ²Associate Professor, ³Director, Professor and Head, Department of Cardiology, GB Pant Hospital, New Delhi, India.

KEY WORDS

Rheumatic mitral regurgitation
Strain rate

A B S T R A C T

Aims: Identification of subclinical left ventricular (LV) dysfunction in patients with rheumatic mitral regurgitation (MR) facilitates optimal surgical results and better postoperative LV function. This study is designed to assess the role of tissue Doppler and strain rate (SR) imaging in early detection of LV systolic dysfunction in patients with asymptomatic chronic severe MR.

Methods and results: Patients were studied under four groups. *Group I:* Normal subject ($n=25$). *Group II:* Patients with chronic severe MR with ejection fraction (EF) $\geq 60\%$ and end-systolic dimension (ESD) ≤ 40 mm ($n=23$). *Group III:* Patients with chronic severe MR with EF $\geq 60\%$ and ESD 41–50 mm ($n=27$). *Group IV:* Patients with chronic severe MR with EF $< 60\%$ with any ESDs ($n=25$). With decrease in EF and increase in ESD there was decrease in systolic velocity and increased in precontraction time and contraction time was noted. The tissue Doppler systolic indices between groups were statistically significant $P < 0.05$ and showed significant correlation value $r=0.45$ between groups. Strain (S) and SR significantly decreased with decrease in EF and increase in ESD $P < 0.05$, $r=0.45$ between different groups.

Conclusion: Our study showed significant correlation between tissue Doppler systolic indices and SR imaging with EF and ESD.

Copyright © 2012, Cardiological Society of India. All rights reserved.

Introduction

Rheumatic chronic severe mitral regurgitation (MR) is a common problem in our country. Patients who are symptomatic or have reduced ejection fraction (EF) have higher late mortality despite valve repair or replacement.^{1,2} Ejection fraction is commonly used to identify patients for surgical reference.³ However, the assessment of EF depends on after load and EF remains higher than normal during compensated phase of chronic MR. Other more sensitive indices than EF have been proposed for detecting early left ventricular (LV) dysfunction in chronic MR: end-systolic volume and end-systolic LV cavity dimension.^{4–6} Measurement of tissue Doppler systolic

indices^{7–10} and assessment of local myocardial deformation using strain (S) and strain rate (SR) imaging has shown to detect regional systolic dysfunction at an earlier subclinical stage than conventional echocardiography.^{11–13}

The aim of the study was to compare tissue Doppler systolic indices, S and SR imaging with conventional parameters EF and end-systolic dimension (ESD) in patients with asymptomatic chronic severe MR.

Materials and methods

Selection of cases

The study was a cross-sectional study involving 75 patients of rheumatic MR conducted over a period of 2 years

*Corresponding author.

E-mail address: sumodkn@yahoo.co.in

(December 2006–November 2008). Informed consent was taken from all persons and included in the study.

Design of study groups

Inclusion criteria: Asymptomatic chronic severe rheumatic MR.
Exclusion criteria: Non-rheumatic MR.

Patients were divided into four groups. *Group I:* Normal subject ($n=25$). *Group II:* Patients with chronic severe MR with EF $\geq 60\%$ and ESD ≤ 40 mm ($n=23$). *Group III:* Patients with chronic severe MR with EF $\geq 60\%$ and ESD 41–50 mm ($n=27$). *Group IV:* Patients with chronic severe MR with EF $< 60\%$ with any ESDs ($n=25$).

Methods

All echocardiographic study was performed using Philips IE-33 machine. The images were acquired from standard parasternal, short axis, and apical views. Standard LV M-mode measurement included estimation of LV end-diastolic dimension and LVESD. Ejection fraction, end-diastolic volume, and end-systolic volume were measured using biplane Simpson's methods.

Mitral regurgitation severity: MR severity was assessed using vena contracta and jet area.

Jet area $> 50\%$ of left atrial and vena contracta > 0.7 cm was taken as criteria for severe MR.

Tissue Doppler imaging

Tissue Doppler imaging (TDI) was performed with minimal optimal gain as possible to obtain the best signal to noise ratio. In the apical four chamber view, pulse Doppler sample volume was placed at the level of basal lateral wall and basal septum. The incidence angle between the interrogating Doppler beam and longitudinal, radial motion of the ventricle was kept as small as possible. The myocardial systolic wave velocity (Sm), myocardial precontraction time (PCT), and myocardial contraction time (CT) were measured. Precontraction time was taken from onset of electrocardiogram QRS to the beginning of Sm. Contraction time was measured from the beginning to the end of Sm.

Strain rate imaging study-data analysis

All data were analysed offline. For the evaluation of longitudinal function, basal LV lateral wall was analysed. For LV radial function, midventricular segment thickening of LV posterior wall was analysed. Peak systolic SR and S during the ejection period were assessed for each segment analysed.¹³ Area of 10 mm (longitudinal) and 5 mm (radial) width of 1 mm (to avoid averaging different ultrasound beams) were used. Frame by frame manual tracking was performed to maintain the computational area within the myocardial region of interest

throughout the cardiac cycle. Values were averaged over three consecutive cycles.

Statistical analysis

The data generated from the above tests was entered in Microsoft Excel. The data was used to compute mean and standard deviation for continuous variables and percentages for categorical variables. Means were compared with independent student's t -test, and percentages were compared with χ^2 test. The Pearson correlation coefficient and ANOVA test were also applied. Differences with probability value ≤ 0.05 were considered significant. The calculations were done using SPSS 13.0 software for windows.

Observations and results

Selection of patients

A total of 75 patients with chronic severe rheumatic MR and 25 healthy controls, were taken for study. Subjects were in the age group of 15–33 years and the mean age was 23.57 ± 5.45 years. Of 100 patients 37 were males (37%) and 63 were females (63%).

Patients were grouped into four groups as shown above. End-diastolic dimension ranged from 4.40 to 9.42 with mean of 6.16 ± 1.46 and ESD varied from 2.36 to 6.53 with mean of 4.19 ± 1.14 in the study group. Ejection fraction varied from 50% to 66.7% with mean of 60.05 ± 5.05 .

Tissue Doppler parameters

With decrease in EF and increase in ESD, there was decrease in systolic velocity and increase in PCT and CT was noted. All this systolic tissue Doppler indices between groups were statistically significant P value < 0.05 and showed significant correlation value $r=0.45$ between groups by using Pearson correlation (Table 1). Same observation was made even from the basal septum with decrease in EF and increase in ESD there was decrease in systolic velocity and increase in PCT and CT (Table 2). All this systolic tissue Doppler indices between groups were statistically significant. P value < 0.05 and significant correlation value $r=0.56$ between groups were found by using Pearson correlation.

Strain rate imaging

Each segmental data set acquired allowed the processing of regional deformation traces which were interpretable. The apical four chamber view was used to quantify longitudinal systolic deformation of basal lateral wall (Table 3). Both S and SR were significantly decreased in patients with decreased EF and increased ESD. P value was significant < 0.05 between different groups and Pearson correlation coefficient was also

Table 1

Tissue Doppler indices from lateral wall.

	Sm	PCT	CT
Group I	9.46±0.29	83.40±3.79	210.00±6.45
Group II	7.96±1.37	103.52±22.86	238.91±34.18
Group III	7.31±1.37	115.00±6.73	256.56±26.36
Group IV	5.70±1.26	133.40±16.25	301.08±38.84

Sm: myocardial systolic wave velocity, PCT: myocardial precontraction time, CT: myocardial contraction time.

Table 2

Tissue Doppler indices from basal septum.

	Sm	PCT	CT
Group I	9.44±0.21	83±1.44	212.40±1.89
Group II	7.75±1.56	96.13±10.66	238.70±25.65
Group III	6.46±1.92	113.41±3.45	296.15±7.53
Group IV	5.44±1.50	133.76±19.16	309.08±33.04

Sm: myocardial systolic wave velocity, PCT: myocardial precontraction time, CT: myocardial contraction time.

Table 3

Myocardial deformation indices from lateral wall.

	Strain %	Strain rate 1/s
Group I	13.00±1.44	1.43±0.16
Group II	8.34±3.62	1.05±0.35
Group III	6.26±1.40	0.80±0.13
Group IV	2.76±2.59	0.74±0.42

Table 4

Myocardial deformation indices from posterior wall.

	Strain %	Strain rate 1/s
Group I	19.60±1.89	1.40±0.20
Group II	11.31±1.40	0.81±0.15
Group III	5.50±1.08	0.70±0.23
Group IV	3.87±0.85	0.58±0.14

significant $r=0.45$. Thus, Table 4 shows that radial S and SR obtained from midventricular posterior wall decreases significantly with decrease in EF and increase in ESD, P value was significant between groups value <0.05 and Pearson correlation coefficient was also significant $r=0.45$ between different groups. Thus, this study shows inverse correlation of radial and longitudinal S and SR with ESD.

Discussion

In the compensated phase of chronic MR, with increasing residual volume, stroke volume has to increase to maintain forward cardiac output. This is affected by an increase in LV end-diastolic volume brought about by a combination of changes in geometry and spherical dilatation along LV short axis.^{14,15} In this situation, the combination of an augmented preload and reduced or normal afterload with maintained intrinsic contractility, preserve LV ejection. In this compensated phase, patients are frequently asymptomatic.³ The duration of the

compensated phase of isolated MR can vary but may last for many years. However, in chronic MR, progressive LV remodelling, with increasing wall stresses due to dilatation, can ultimately lead to irreversible changes in the myocardium, resulting in the development of LV contractile dysfunction. From our study, we found that a large number of patients with severe MR and reduced deformation have an EF $>60\%$, indicating that EF might not be the most sensitive parameter to evaluate these patients. Even in patients with LVESD below conventionally accepted value of 45 mm, deformation indices were significantly deranged. This suggest that the usage of these indices would be more sensitive in identifying the onset of LV dysfunction in patients with chronic severe MR facilitating optimal reference for surgery resulting in optimal surgical results and better postoperative LV function.

Tissue Doppler systolic indices

Tissue Doppler systolic indices not only define and measure mitral annular movements but, because of high temporal resolution, also provide a useful estimate of myocardial (both systolic and diastolic) time intervals.^{16,17} In our study, positive correlation was found between tissue Doppler systolic indices and EF and ESD (P value <0.05). Tissue Doppler systolic indices systolic velocity may be a more sensitive marker than EF as TDI indices are relatively independent of preload and architecture and activation of myocardial fibre.¹⁸ This would mean that TDI assessment may be useful to obtain evidence of subclinical myocardial dysfunction and thereby significantly optimise the timing of mitral valve surgery.

Strain rate imaging

Myocardial deformation (S), and the speed at which this deformation takes place (SR) reflects systolic function and are the result of the intrinsic contractility (force development) of the myocardium acting to overcome loading conditions and thus ejecting the required blood volume into circulation. Our study showed a significant correlation between radial and longitudinal S and SR with ESD and EF. In our study, with decreasing EF and increasing ESD, there was a significant decrease in radial and longitudinal S and SR (P value <0.05).

The results were comparable to previous study by Weidemann et al. in which they have shown that deformation (S) decreasing with decreasing stroke volume and that deformation rate (SR) changes similarly.¹²

In all patients with an ESD >4 cm, regional deformation (rate) values were significantly reduced but importantly it should be noted that decrease in SR and S values, even more than predicted by geometry, occurred before ESD reached 4 cm.

Thus, our study showed a significant correlation between tissue Doppler systolic indices and SR imaging with EF and ESD. The measuring parameters (Sm, PCT, CT, S, and SR) showed alterations even with EF $>60\%$ and ESD <4 cm in patients with chronic asymptomatic severe MR. This indicates the

usefulness of these parameters in detecting subclinical LV dysfunction beyond the conventionally accepted criteria using EF and ESD.

Conclusion

Significant decrease in systolic velocity and increase in PCT and CT occurred in relation to decrease in EF and increase in ESD (P value <0.05). There was also a significant decrease in both radial and longitudinal S and SR with decreasing EF and increasing ESD (P value <0.05). Our result also showed that myocardial deformation changes with changing geometry of the ventricle. The tissue Doppler indices appears to have good correlation with LVEF and ESD and are altered even before the conventional echocardiographic criteria for surgical reference (EF $<60\%$ and LVESD >45 mm) is reached. Careful postoperative follow-up is required for these indices to have clinical implication.

Limitations

Our study is a cross-sectional study without longitudinal follow-up and needs to be followed up postoperatively to have prognostic implication.

References

1. Ling LH, Enriquez-Sarano M, Seward JB, et al. Clinical outcome regurgitation due to flail leaflet. *N Engl J Med* 1996;335:1417–23.
2. Avierinos JF, Gersh BJ, Melton LN, et al. Natural history of asymptomatic mitral valve prolapse in the community. *Circulation* 2002;106:1355–61.
3. Bonow RO, Carabello B, de Leon AC Jr, et al. Guidelines for the management of patients with valvular heart disease: executive summary. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Patients with Valvular Heart Disease). *Circulation* 1998;98:1949–84.
4. Wisenbaugh T, Skudicky D, Soreli P. Prediction of outcome after valve replacement for rheumatic mitral regurgitation in the era of chordal preservation. *Circulation* 1994;89:191–7.
5. Enriquez-Sarano M, Tajik A, Schaff H, et al. Echocardiographic prediction of left ventricular function after correction of mitral regurgitation: results and clinical implications. *J Am Coll Cardiol* 1994;24:1536–43.
6. Zile MR, Gaasch WH, Carroll JD, et al. Chronic mitral regurgitation: predictive value of preoperative echocardiographic indexes of left ventricular function and wall stress. *J Am Coll Cardiol* 1984;3:235–42.
7. Bruch C, Stypmann J, Gradaus R, Breithardt G, Wichter T. Impact of stroke volume on mitral annular velocities derived from tissue Doppler imaging. *Heart* 2005;91:243–4.
8. Haluska BA, Short L, Marwick T. Relationship of ventricular longitudinal function to contractile reserve in patients with mitral regurgitation. *Am Heart J* 2003;146:183–8.
9. Agricola E, Galderisi M, Oppizzi M, et al. Pulsed tissue Doppler imaging detects early myocardial dysfunction in asymptomatic patients with severe mitral regurgitation. *Heart* 2004;90:406–10.
10. Tsutsui H, Uematsu M, Shimizu H, et al. Comparative usefulness of myocardial velocity gradient in detecting ischemic myocardium by a dobutamine challenge. *J Am Coll Cardiol* 1998;31:89–93.
11. Weidemann F, Kowalski M, D'hooge J, Bijnens B, Sutherland GR. Doppler myocardial imaging. A new tool to assess regional inhomogeneity in cardiac function. *Basic Res Cardiol* 2001;96:595–605.
12. Weidemann F, Jamal F, Sutherland GR, et al. Myocardial function defined by strain rate and strain during alterations in inotropic states and heart rate. *Am J Physiol Heart Circ Physiol* 2002;283:H792–9.
13. D'hooge J, Heimdal A, Jamal F, et al. Regional strain and strain rate measurements by cardiac ultrasound: principles, implementation and limitations. *Eur J Echocardiogr* 2000;1:154–70.
14. Vokonas PS, Gorlin R, Cohn PF, Herman MV, Sonnenblick EH. Dynamic geometry of the left ventricle in mitral regurgitation. *Circulation* 1973;48:786–96.
15. Hiro T, Katayama K, Miura T, et al. Stroke volume generation of the left ventricle and its relation to chamber shape in normal subjects and patients with mitral or aortic regurgitation. *Jpn Circ J* 1996;60:216–27.
16. Fukuda K, Oki T, Tabata T, et al. Regional left ventricular wall motion abnormalities in myocardial infarction and mitral annular descent velocities studies with pulsed tissue Doppler imaging. *J Am Soc Echocardiogr* 1998;11:841–8.
17. Caso P, Galderisi M, D'Andrea A, et al. Analysis by pulsed doppler tissue imaging of ventricular interaction in long-distance competitive swimmers. *Am J Cardiol* 2002;90:139–7.
18. Naqeh SF, Middleton KJ, Kopelen HA, et al. Doppler tissue imaging: a technique for evaluation of left ventricular relaxation and estimation of filling pressures. *J Am Coll Cardiol* 1997;30:1527–33.