CARDIAC IMAGE UPDATED

Vol. 1, No. 3, July-September 2019

doi: 10.35366/91807
https://dx.doi.org/10.35366/91807

Original Research

Left ventricular mechanics behavior according to degenerative mitral regurgitation severity

Comportamiento de la mecánica del ventrículo izquierdo según la severidad de la regurgitación mitral degenerativa

Nydia Ávila Vanzzini,* Juan Francisco Fritche-Salazar,* Néstor Alejandro Parra-Ordóñez,* Héctor Herrera-Bello‡

* National Cardiology Institute «Ignacio Chávez».
‡ Médica Sur Clinical Foundation.

ABSTRACT. Degenerative mitral regurgitation (MR) is a progressive condition, the optimal time for surgical correction often goes unnoticed. Left ventricle (LV) mechanics evolution assessed by echocardiography might be an important diagnostic tool. Currently, little is known about ventricular mechanics and left ventricular compensatory mechanisms to maintain adequate cardiac output in the context of degenerative MR. Our objective was to describe the LV mechanics behavior in patients with different degrees of degenerative MR and compare them with a healthy control group. **Methods:** An observational, cross-sectional, comparative and analytical study was designed. Ventricular mechanics analysis was performed using GE system. The patients were grouped in mild, moderate or severe MR. **Results:** Ninety-one participants were included, 57 cases and 34 controls. The case group presented a significant decrease in longitudinal, radial and circumferential strain, as well as, diminution of twist and torsion in relation to the control group. According to the severity of the mitral regurgitation, the global longitudinal strain (GLS) showed a significant progressive decrease from -20%, -18% and -14% in mild, moderate and severe MR respectively, (p=0.03). The same scenario was observed in global circumferential and radial strain; rotational mechanics with twist and torsion decreasing from mild to severe MR (p=0.034, p=0.038 respectively). **Conclusion:** Alterations in LV mechanics are seen in moderate and severe degrees of MR, this could expose a lack of compensatory mechanisms to maintain ventricular function as the pathology progresses.

Keywords: Mitral regurgitation, ventricular mechanics, strain, twist, torsion.

RESUMEN. *La insuficiencia mitral degenerativa (IM) es una condición progresiva; el momento óptimo para la corrección quirúrgica a menudo pasa desapercibido. La evolución de la mecánica del ventrículo izquierdo (VI) evaluada mediante ecocardiografía podría ser una herramienta diagnóstica importante. Actualmente, se sabe poco sobre la mecánica ventricular y los mecanismos compensatorios del VI para mantener un gasto cardiaco adecuado en el contexto de la IM degenerativa. Nuestro objetivo fue describir el comportamiento de la mecánica del VI en pacientes con diferentes grados de IM degenerativa y compararlos con un grupo de control saludable.* ***Métodos:*** *Se diseñó un estudio observacional, transversal, comparativo y analítico. El análisis de la mecánica ventricular se realizó utilizando el sistema GE. Los pacientes se agruparon en IM leve, moderada o grave.* ***Resultados:*** *Se incluyeron 91 participantes, 57 casos y 34 controles. El grupo de casos presentó una disminución significativa en la distensión longitudinal, radial y circunferencial, así como en el giro y torsión, en relación con el grupo de control. De acuerdo con la gravedad de la IM, la distensión longitudinal global (GLS) mostró una disminución progresiva de -20%, -18% y -14% en MR leve, moderada y severa, respectivamente (p=0.03). El mismo escenario se observó en la distensión circunferencial y radial global; la mecánica rotacional con giro y torsión disminuyeron progresivamente, según la severidad de la IM (p=0.034, p=0.038, respectivamente).* ***Conclusión:*** *Se observan alteraciones en la mecánica del VI en grados moderados y severos de IM, lo que podría exponer una falta de mecanismos compensatorios para mantener la función ventricular a medida que avanza la patología.*

Palabras clave: *Insuficiencia mitral, mecánica ventricular, distensión, giro, torsión.*

Corresponding author:
Nydia Ávila-Vanzzini
Department of Out Patiets Care,
National Cardiology Institute «Ignacio Chávez»,
Juan Badiano Núm.1,
14080,
Col. Sección XVI,
Alcaldía Tlalpan, Ciudad de México
Tel: +52 (55) 55-73-29-11,
Fax: +52 (55) 55730994
E-mail:
vazzny74@yahoo.com

INTRODUCTION

Degenerative mitral regurgitation (MR) is a volume overload progressive condition, causing left ventricle (LV) morphological changes such as sphericity and dilation; the volume excess causes elevated diastolic stress which triggers increase in ventricular mass (Laplace's law), the thickness of the ventricular wall will increase eccentrically in proportion to the dilatation of the LV. On the other hand, the insufficient coaptation of the mitral valve during systole, allows the flow and pressure to escape into the atrium (low pressure cavity), at the end of the systole the wall stress (afterload) is normal or even diminished which causes further myofibrillar damage.[1] The combination of volume overload and decreased afterload results in a normal or supranormal ejection fraction and since the left atrium (LA) remodeling allows a larger volume, clinical tolerance is excellent. In this deceptive context, in which the patient has no symptoms and ventricular function is normal, the step between ventricular compensation and myocardial damage is virtually imperceptible; It has been called «subclinical damage» and is associated with the

Table 1: Demographic and echocardiographic findings in patients with chronic mitral regurgitation and control groups.

	Control group n=34	MR n=57	p
Age (years)	26 (21-33)	54 (47-62)	0.000
Female(%)	19 (55.8)	32 (56.1)	0.981
Height (cm)	167 ± 10	170 ± 11	0.009
Weight (kg)	67 (56-78)	68 (59-76)	0.457
Hypertension (%)	0	21 (36.8)	0.000
Dyslipidemia (%)	0	14 (24.5)	0.002
Echocardiographyc findings			
LV EDV (mL)	48 (42-55)	65 (49-101)	0.007
LV ESV (mL)	30 (24-38)	43 (28-60)	0.028
LAVI (mL/m2)	15 (11-19)	23 (19-35)	0.000
LVEF (%)	60 (60-65)	55 (49-60)	0.000
Mitral valve measurements			
MA in diastole (mm)	31 ± 3.8	33 ± 5.3	0.081
MA in systole (mm)	24 (20-28)	28 (23-33)	0.024
MA shortening (%)	21 (15-28)	12 (6-21)	0.018
Tenting area (cm2)	0.9 (0.7-1.4)	1.9 (1.6-2.5)	0.000
Deep of coaptation (mm)	0.7 (0.6-0.9)	1 (0.7-1.2)	0.001
LV mechanics			
GLS (%)	-22 (-23 to -20.5)	-17.4 (-21.8 to -12.7)	0.000
GCS (%)	-25 (-29 to -20)	-16.3 (-21 to -13)	0.000
GRS (%)	42 (33 to 47)	22 (15.9 to 34)	0.000
Basal rotation (º)	-6 (-7.3 to -4.5)	-4.6 (-7 to -3)	0.121
Apical rotation (º)	11 (9.6 to 11.9)	10 (6 to 13)	0.050
Twist (º)	17 (15 to 18)	14 (10 to 18)	0.007
Torsion (º/cm)	2.0 (1.8 to -2.2)	1.8 (1.3 to 2.3)	0.047

LV = Left ventricle; EDV = End-diastolic volume; ESV = End-systolic volume; LAVI = Left atrial volume index; LVEF = Left ventricular ejection fraction; MA = Mitral annulus; GLS = Global longitudinal strain; GCS = Global circumferential strain; GRS = Global radial strain.

www.medigraphic.org.mx

Table 2: Demographic and echocardiographic findings according to mitral regurgitation severity.

	Mild n = 26	Moderate n = 12	Severe n = 19	p
Age (years)	51 (44-62)	54 (46-60)	55 (47-62)	0.824
Female (%)	15 (58)	9 (75)	8 (42)	0.089
Height (cm)	162 ± 12	159 ± 10	161±9	0.701
Weight (kg)	67 (55-71)	67 (58-76)	68 (57-75)	0.138
Hypertension (%)	8 (31)	5 (42)	8 (42)	0.684
Dyslipidemia	6 (23)	3 (25)	5 (26)	0.969
Echocardiographyc findings				
LV EDV (mL)	44 (44-58)	57 (44-87)	79 (51-97)	0.002
LV ESV (mL)	19 (13-31)	25 (16-39)	32 (23-62)	0.008
LAVI (mL)	40 (32-50)	61 (51-68)	79 (74-128)	0.001
LVEF (%)	60 (55-61)	58 (53-63)	50 (26-55)	0.013
Mitral valve measurements				
MA diastole (mm)	30 ± 4	32 ± 5	36 ± 5	0.001
MA systole (mm)	25 ± 4	26 ± 6	34 ± 5	0.000
MA shortening (%)	17 (7-24)	17 (11-29)	6 (2-12)	0.000
Tenting area (cm2)	1.6 (1.1-2.1)	1.8 (1.4-2.1)	2.5 (2.3-3.1)	0.000
Deep of coaptation (mm)	0.9 (0.6-1)	0.95 (0.8-1.1)	1.1 (0.9-1.4)	0.045
LV mechanics				
GLS (%)	-20 (-23 to-17.7)	-18 (-21 to -15.7)	-14 (-17.8 to-6.7)	0.033
GCS (%)	-22 (-22 to -15)	-18.3 (-20.5 to -15.5)	-15 (-17.2 to -8)	0.141
GRS (%)	36.5 (22-38)	24 (17.5-28.5)	19 (14-27)	0.099
Basal rotation (o)	-6 (-8.2 to -3.7)	-4.5 (-6.3 to -2.4)	-3.4 (-6 to -1.9)	0.083
Apical rotation (o)	10.8 (7.3-13)	9.5 (7.6-13)	6.5 (4.2-14.5)	0.304
Twist (o)	16 (13.6-19.4)	14.5 (11.4-17)	10.3 (7.3-14.3)	0.034
Torsion (º/cm)	2.05 (1.6-2.4)	1.65 (1.35-2.2)	1.1 (0.8-2.1)	0.038

LV = Left ventricle, EDV = End-diastolic volume, ESV = End-systolic volume; LAVI = Left atrial volume index; LVEF = Left ventricular ejection fraction; MA = Mitral annulus; GLS = Global longitudinal strain; GCS = Global circumferential strain; GRS = Global radial strain.

appearance of interstitial fibrosis and decrease in the number and function of myofibrils.[1] Ideally, in an asymptomatic patient, surgery should take place when left ventricular ejection fraction (LVEF) is still normal, but myocardial dysfunction is imminent. An important diagnostic tool might be the evaluation of the evolution of LV mechanics by echocardiography. There is strong evidence that in multiple cardiac diseases the prognostic value of LV global longitudinal strain (GLS) is superior to that of LVEF when it comes to predicting LV dysfunction and major adverse cardiac events.[2] In patients with asymptomatic MR and preserved ejection fraction at 2 weeks postoperatively there was a positive correlation between GLS ≤ 18% and a postoperative decrease in LVEF by >10%.[3] Mentias et al. with 737 asymptomatic patients with primary severe MR, a non-dilated LV and a preserved LVEF, showed that a GLS value below -21.7% was independently associated with mortality [HR 1.60, 95%CI 1.47-1.73] and provided additive prognostic utility to previously known predictors.[4] In addition to the longitudinal deformation vector, the remaining vectors are gradually affected by compromising the rotational mechanisms and denoting greater ventricular damage. In chronic dilated cardiomyopathy patients, torsional profile was more altered in severe MR. Endocardial basal rotation, endocardial

www.medigraphic.org.mx

torsion, and circumferential strain, can be used as indicators of advanced structural wall architecture damage.[5] Ventricular dilation is associated with stretching and reorientation of muscle fibers, which reduces contractility, regardless of changes in volume and contractile strength, leading to reduced values in cardiac torsion and twist, considering them as a sensitive marker of alterations in ventricular architecture in an incipient manner.[6] Currently, little is known about complete ventricular mechanics and the compensatory mechanisms of LV to maintain adequate cardiac output in the context of degenerative MR. The objective of our study was to describe the behavior of LV mechanics of patients with degenerative MR at different degrees of severity, comparing them with the control group.

METHODS

An observational, cross-sectional, comparative and analytical study was designed. All patients over 18 years who attended the echocardiography laboratory with diagnosis of degenerative MR regardless of the severity and LVEF ≥30% were included consecutively during a period of six months. They agreed to participate in the study by signing an informed consent. Patients with other associated valvular lesions (except mild tricuspid insufficiency), history of ischemic heart disease, idiopathic dilated cardiomyopathy, previous cardiac surgery, systemic or inflammatory diseases, history of chemotherapy or radiotherapy, poor acoustic window and no sinus rhythm were excluded. A young, healthy control group was included also. The study was approved by the local research committee and follows the Helsinki line.

Echocardiographic evaluation: Conventional transthoracic 2D echocardiograms were performed with a GE vivid 9 XD Clear ultrasound system, following current guidelines.[7]

Evaluation of mitral regurgitation. Depending on the number of jets observed, we use two main measurement methods: in the case of a single jet, the contracted vein (CV) was measured in the axis perpendicular to the regurgitant jet; a CV < 0.3 cm was equivalent to mild insufficiency, a CV ≥0.7 cm was equal to severe regurgitation, the intermediate points were evaluated with quantitative methods such as the flow convergence method (PISA). If two or more jets were observed, the severity assessment was carried out using Doppler continuity method, in accordance with the recommendations for the evaluation of valvular regurgitation.[8] In both methods, PISA and continuity, an effective regurgitant orifice area (EROA) ≥0.40 cm^2 and regurgitant volume (RVol) ≥60 mL was considered as severe MR; EROA of 0.20-0.39 cm^2 and RVol of 30-59 mL was considered moderate, and EROA <20 cm^2 and <30 mL of RVol, was considered mild.

Ventricular mechanics analysis

For the analysis of ventricular mechanics, apical approaches (4C, 2C, 3C) and the parasternal short axis (basal, middle and apical) were

Table 3: Schematic description of the behavior of ventricular mechanics in different degrees of mitral regurgitation.

	Control group	Mild MR	Moderate MR	Severe MR
GLS (%)	-22	-20 N	-18	-14
GCS (%)	-25	-22 N	-18	-15
GRS (%)	42	36 N	24	19
Twist (°)	17	16 N	14.5 N	10.3
Torsion (°/cm)	2.0	2.0 N	1.65 N	1.1

GLS = Global longitudinal strain, GCS = Global circumferential strain, GRS = global longitudinal strain.

www.medigraphic.org.mx

Table 4: Interobserver variability analysis.

	Correlation coefficient	p
GLS	0.955	0.000
GRS	0.790	0.015
GCS	0.975	0.000
Basal rotation	0.892	0.001
Apical rotation	0.738	0.029
Twist	0.778	0.018
Torsion	0.821	0.009

GLS = Global longitudinal strain, GCS = Global circumferential strain, GRS = Global radial strain.

obtained, maintaining an adequate gray scale (60-80 frames/s) according to guidelines.[9] The 2D deformation analysis was performed by post-process at the EchoPAC (GE) workstation.

The patients were grouped according to the severity of MR in mild, moderate or severe, the ejection fraction of the LV was estimated by Simpson's biplane method.

Statistic analysis

Normality of the continuous variables was sought with the Shapiro Wilk test. The parametric variables are expressed as mean and standard deviation and their comparison was made with Student's t-test; the non-parametric variables are expressed in median and interquartile range; their comparison was made with Wilcoxon test. The comparison of more than two groups of continuous variables was performed with analysis of variance (one way ANOVA) or the Kruskal-Wallis test as appropriate. Categorical variables are expressed as percentage and their comparison between groups was performed with the χ^2 test. A p value <0.05 was considered as statistically significant.

RESULTS

A total of 91 participants were included, 57 were cases and 34 controls. Differences in age, height, hypertension and dyslipidemia were observed between groups, in the echocardiographic findings there was a significant difference in LVEF, end-diastolic volume, end-systolic volume, LA volume, dimension and fractional shortening of the mitral annulus, tension area and depth of coaptation. In ventricular mechanics the case group presented a significant decrease in longitudinal, radial and circumferential strain, as well as, lower twist and torsion compared to the control group *(Table 1)*.

Analysis of cases according to the severity of mitral regurgitation. According to the degree of the mitral regurgitation, a progressive decrease in the LVEF and shortening of mitral annulus was found; along with an increase in volumes in LV and LA, tension area and deep of coaptation of the mitral valve *(Table 2)*.

The GLS showed a significant progressive decrease ($p <0.03$) from -20, -18 and -14% in mild, moderate and severe MR respectively. The same scenario was observed in GCS and GRS, the higher the MR, the lower the deformation values *(Table 2)*. The twist in patients with mild MR was 16º which decreases to 10.3º in severe MR ($p <0.034$); torsion shows a similar pattern with a value of 2.05º/cm in the mild degree of MR, and that decreases 1.1º/cm in severe MR ($p <0.038$) *(Table 2 and 3)*.

Interobserver variability

Interobserver variability analysis was performed using intraclass correlation coefficient for longitudinal, circumferential and radial strain and for apical rotation, basal rotation and twist, a variability of 5% and 3% was obtained for longitudinal and circumferential strain respectively ($p <0.0001$), similar findings to what has previously been reported *(Table 4)*.

DISCUSSION

This study describes the behavior of LV mechanics in primary chronic mitral regurgitation at different stages of severity. It was found that during the evolution of the pathology the ventricular mechanics gradually deteriorates until there is a decrease in the ejection fraction and cardiac failure.

www.medigraphic.org.mx

Compared against the control group, mild MR has a similar ventricular mechanic behavior, however, in moderate and severe MR, the three deformation vectors were decreased. Rotational mechanics showed to be normal in mild and moderate MR, with a significant fall in severe MR. The scenario is different in valvular diseases with high or constant systolic stress, where there are compensatory mechanisms such as increased circumferential strain, twist and torsion.[10] We observed that MR does not really have ventricular compensatory mechanisms that allow it to protect from ventricular failure.

Chronic MR is characterized by volume overload, increased diastolic stress and low impedance, since systolic flow finds an escape to the LA (low pressure cavity); this generates an adverse remodeling of the LV and a rapid progression to heart failure.[3] Based on our findings, when valvopathy is characterized by high volume and low systolic stress, the ventricle is not able to develop compensatory mechanisms and the progression towards deterioration and heart failure is imminent. Despite the deterioration of ventricular mechanics in most cases, the LVEF remains at normal parameters.

LV rotational mechanics is a potentially valuable biomarker of LV dysfunction; we observed that the LV rotational mechanics became more compromised as the severity of the MR increases. This same behavior has been reported by Reyhan M et al.,[11] describing how in moderate MR patients only the apical rotation was decreased, while in severe MR patients both basal and apical rotation were affected. Reduction in LV twist in patients with MR is consistent with previous reports.[12,13] The decrease in apical rotation may be due to spherical remodeling of the mid-ventricular and apical LV,[14] it has been suggested that chronic MR reduces systolic torsion of LV as a result of decreased «leverage» of epicardial fibers (whose contraction produces positive torsion) in relation to endocardial muscle fibers (which produce negative torsion).[11,13]

Limitations: the transversal nature or this study is in itself a limitation. Long-term studies, with a greater number of participants are needed to fully understand ventricular behavior due to volume overload and low systolic stress.

CONCLUSION

Alterations in LV mechanics are observed in moderate and severe MR and reflect the natural history of primary chronic MR, in which the ventricle cannot develop compensatory mechanisms to maintain ventricular function as the disease progresses.

REFERENCES

1. Michelena HI, Topilsky Y, Suri R et al. Degenerative mitral valve regurgitation: understanding basic concepts and new developments. Postgraduate Medicine. 2011; 123 (2): 56-69.
2. Kalam K, Otahal P, Marwick TH. Prognostic implications of global LV dysfunction: a systematic review and meta-analysis of global longitudinal strain and ejection fraction. Heart. 2014; 100 (21): 1673-1680.
3. Pandis D, Sengupta PP, Castillo JG, et al. Assessment of longitudinal myocardial mechanics in patients with degenerative mitral valve regurgitation predicts postoperative worsening of left ventricular systolic function. J Am Soc Echocardiogr. 2014; 27 (6): 627-638.
4. Mentias A, Naji P, Gillinov AM, et al. Strain echocardiography and functional capacity in asymptomatic primary mitral regurgitation with preserved ejection fraction. J Am Coll Cardiol. 2016; 68 (18): 1974-1986.
5. Kinova E, Spasova N, Borizanova A, et al. Torsion mechanics as an indicator of more advanced left ventricular systolic dysfunction in secondary mitral regurgitation in patients with dilated cardiomyopathy: a 2D Speckle-Tracking analysis. Cardiology. 2018; 139 (3): 187-196.
6. Sengupta PP, Krishnamoorthy VK, Korinek J, et al. Left ventricular form and function revisited: applied translational science to cardiovascular ultrasound imaging. J Am Soc Echocardiogr. 2007; 20 (5): 539-551.
7. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr. 2015; 28 (1): 1-39.
8. Lancellotti P1, Moura L, Pierard LA, et al. European Association of Echocardiography recommendations for the assessment of valvular regurgitation. Part 2: mitral and tricuspid regurgitation (native valve disease). Eur J Echocardiogr. 2010; 11 (4): 307-332.
9. Mor-Avi V, Lang RM, Badano LP, et al. Current and evolving echocardiographic techniques for the quantitative evaluation of cardiac mechanics: ASE/EAE consensus statement on methodology and

www.medigraphic.org.mx

indications endorsed by the Japanese Society of Echocardiography. J Am Soc Echocardiogr. 2011; 24 (3): 277-313.
10. Carasso S, Cohen O, Mutlak D, et al. Relation of myocardial mechanics in severe aortic stenosis to left ventricular ejection fraction and response to aortic valve replacement. Am J Cardiol. 2011; 107 (7): 1052-1057.
11. Reyhan M, Wang Z, Li M, et al. Left ventricular twist and shear in patients with primary mitral regurgitation. Journal of magnetic resonance imaging. J Magn Reson Imaging. 2015; 42 (2): 400-406.
12. Borg AN, Harrison JL, Argyle RA, et al. Left ventricular torsion in primary chronic mitral regurgitation. Heart. 2008; 94 (5): 597-603.
13. Tibayan FA, Yun KL, Fann JI, et al. Torsion dynamics in the evolution from acute to chronic mitral regurgitation. J Heart Valve Dis. 2002; 11 (1): 39-46; discussion 46.
14. Schiros CG, Dell'Italia LJ, Gladden JD, et al. Magnetic resonance imaging with 3-dimensional analysis of left ventricular remodeling in isolated mitral regurgitation: implications beyond dimensions. Circulation. 2012; 125 (19): 2334-2342.

www.medigraphic.org.mx