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ORIGINAL ARTICLE

Color M-mode Regurgitant Flow Propagation Velocity: A New Echocardiographic Method for Mitral Regurgitation Assessment :3D Color Doppler Correlation

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Background Doppler echocardiography has high sensitivity in detecting mitral regurgitation and Doppler color flow mapping is the most widespread method in clinical practice to assess the severity of MR.

Aim The present study aimed to evaluate the reliability of mitral regurgitation color M- mode regurgitation flow propagation velocity MRFPV in assessment of mitral regurgitation.

Methods The present study enrolled 35 patients having variable degrees of Mitral regurgitation (mild–moderate- severe), 20 of them rheumatic MR and 10 congenital MR, 5 mitral valve prolapse. All patients were subjected to: 2D echocardiography to establish the diagnosis & to exclude patients who are not fitting the criteria, pulsed Doppler assessment of mitral regurgitation degree (mild, moderate, severe), 3 D color Doppler assessment of mitral regurgitation and mitral regurgitation color M-mode flow propagation velocity.

Results There was a high correlation between the grade of mitral regurgitation by 3D color Doppler analyses and the flow propagation velocity as measured by color M-mode Doppler recording r= 0.96, p <0.001. The mean values of RFPV does not change significantly in patients both with normal and low left ventricular ejection fraction after grouping of mild, moderate and severe MR concerned (p> 0.05).

Conclusions Mitral regurgitation flow propagation velocity is a simple and reliable method for grading of mitral regurgitation.

Keywords Mitral regurgitation flow propagation velocity, Mitral regurgitation, Three dimensional echocardiography.
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INTRODUCTION

Estimation of severity has become a significant predictor of outcomes and a pivotal factor in the management of mitral regurgitation (1).

Color Doppler flow imaging is the most widely used technique for assessing mitral regurgitation, but eccentric regurgitant jets cannot be visualized and measured by conventional 2D techniques. A new procedure was developed for quantitative analysis of mitral eccentric regurgitation jet based on real-time three-dimensional color Doppler flow images with mitral regurgitation and 3D acquisition. The experiments display the mitral regurgitation volume tendency chart within different systolic phase and the regurgitation volumes were measured by real-time 3D Color Doppler. A higher degree of mitral regurgitation was found in the patients with eccentric jets. While traditional 2D color Doppler jet areas failed to identify patients with different grades of regurgitation, jet volumes could so discriminate. Real-time 3D Doppler revealed new patterns of regurgitant flow and allowed a more accurate semi-quantitative assessment of complex eccentric regurgitant jets. The Real-time three-dimensional color Doppler has a great potential for becoming a reference method for the assessment of eccentric regurgitant with heart valve disease (2).

Color M-mode regurgitant flow propagation velocity is a new echocardiographic method for grading of mitral regurgitation (3), Akdemir, et al. previously examined 52 consecutive patients with grades of MR mild in 10 patients, moderate in 19 patients, and severe in 23 patients with quantitative pulse Doppler echocardiography.

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Abbreviations and Acronyms

MRFPV	: Mitral regurgitation flow propagation velocity
MR	: Mitral regurgitation
3D	: Three dimensional

MR was evaluated by vena contracta diameter (VCD), regurgitant jet area (RJA), and RFPV. These qualitative and quantitative methods were compared with the pulsed Doppler quantitative flow measurements and concordance of these three methods was determined. RFPV was highly sensitive in differentiating mild and severe MR from other subgroups. Significant correlation was observed between pulse Doppler quantitative grades. So they suggested that RFPV is a reliable and simple semiquantitative new method that can be used for determining severity of mitral regurgitation .

AIM

The present study aimed to evaluate the reliability of mitral regurgitation color M- mode regurgitant flow propagation velocity (MRFPV) in assessment of mitral regurgitation .

PATIENTS AND METHODS:

The study enrolled 35 patients having variable degrees of Mitral Regurge, 20 Patients having rheumatic mitral regurgitation, 10 patients congenital MR, 5 mitral valve prolapse. Rheumatic group age ranging from 6-16 years old, 8 of them were males, 12 of them were females. Congenital group age ranging from 0.3 -4 years, 4 were males and 6 females .Mitral prolapse group age ranging from 8-16 years, 4 were females and one male.

all patients were subjected to:

1. Full history & clinical examination.
2. Echocardiographic evaluation (Using GE Vivid 7 ultrasound instrument) including:

- 2D echocardiographic to establish the diagnosis & to exclude patients who aren't fitting the criteria.
- 2D pulsed Doppler assessment of mitral regurgitation (Mild, moderate, severe).
- Mitral Regurgitation color M-mode flow propagation velocity.
- 3D color Doppler assessment.

mitral regurgitation color m-mode flow propagation velocity:

Color M-mode measurements (3) was obtained from apical five chamber view or epical long axis view. M-mode cursor placement was attempted to be as parallel to mitral regurgitation flow obtained by color doppler as possible using 3.5 MHZ probe, GE Vivid 7 ultrasound instrument.

Before the color M- mode doppler measurement, color scale of the equipment was adjusted for aliasing. The narrowest sector angle that allow best visualization of the regurgitant jet was used and color M-mode Doppler recording was performed. Adjustments had been made to obtain the longest column of flow from the mitral valve to left atrium. Color M-mode doppler Echocardiogram was recorded on a compact disc flow propagation volcity was measured as the slope of the first aliasing velocity from the mitral valve to left atrium cavity (cm/sec). The slope of color M-Mode flow was descriped as the slope of a line hand-drawn along the color/no-color. Zoom mode was used to optimize visualization and measurements of the color M-mode flow propagation velocity (Figure 1).

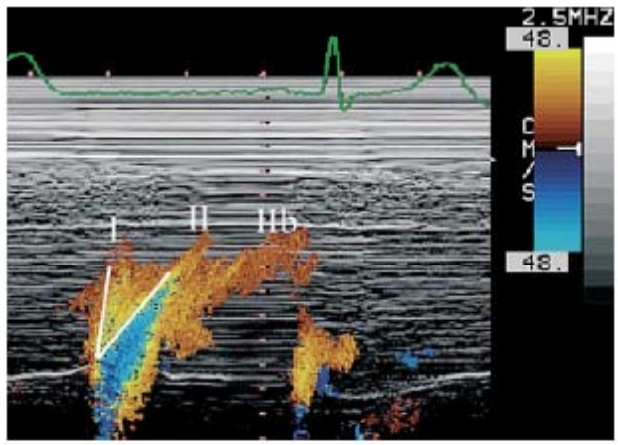

Figure 1: Representative example of a color M-mode image of left ventricular inflow, Phase I: the pressure wave has a high propagation velocity but low blood velocities (I). In phase II, the flow wave (Vortex) propagation can be appreciated (II) as well as the propagation of a secondary vortex.

color doppler 3D echocardiography (4):

Color Doppler 3D echocardiography was applied for direct measurement, in "En face" view, of mitral effective regurgitant orifice area (EROA); Regurgitation volume was subsequently calculated as EROA multiplied by the velocity-time integral of the regurgitant jet on the continuous-wave Doppler.

Statistical Analyses: All values were given as mean ± standard deviation. MR. Correlations between MR FPV and 3D color Doppler grading were obtained by using the Pearson correlation and linear regression analysis. P values <0.05 were considered significant.

RESULTS

The present study evaluated 30 patients, 20 of them were mitral regurgitation of Rheumatic origin, 10 of them were congenital mitral regurgitation , both groups having variable degrees of mitral regurgitation (Assessed by pulsed Doppler).

The 20 rheumatic patient , 10 of them having severe MR 6 of them having moderate MR, 4 of them having mild MR (as assessed by pulsed Doppler), their age ranging from 6-16 years old, 8 of them were males, 12 of them were females (Table 1) , 9 of them having isolated MR, 5 of them associated with mild mitral stenosis and other 6 cases associated with mild Aortic regurgitation.

- Left ventricular end diastolic diameter was increased in severe MR patients and ejection fraction show no significant difference in between the 3 subgroups of MR (Mild, moderate severe).
- 10 patients of congenital MR, 6 of them having moderate MR, one severe MR and 3 of them having mild MR (as assessed by pulsed Doppler), the mean age ranging from 2 months to 4 years, 6 were females and 4 were males (Table 1). 3 of them having isolated MR, 7 of them associated with other congenital anomalies.
- 5 patients diagnosed as mitral valve prolapse, 4 females And one male, range of age (8-14). Mitral regurgitation was mild in 3 cases and moderate in 2 cases (Table 1) .
- The values of flow propagation velocity were (11-29 cm/sec), mean+SD (20+9) in mild MR group, (32-50 cm/sec), mean+SD (41+9), in moderate MR group and (50-90 cm/sec), mean+SD (70+20) in severe MR group (Table 2).
- 3D color Doppler assessment of mitral regurgitation by measuring effective regurgitation orifice area (EROA), velocity time integral (VTI), regurgitation volume= EROA multiplied by VTI. (Mean+SD) in mild, moderate and severe mitral regurgitation calculated (Table 3).
- There was a high correlation between the grade of mitral regurgitation by 3D color Doppler analyses and the flow propagation velocity as measured by color M-mode Doppler recording r= 0.96, p <0.001. The mean values of RFPV does not change significantly in patients both with normal and low left ventricular ejection fraction after grouping of mild, moderate and severe MR concerned (p >0.05).

Table 1: Demographic characteristics of studied groups:

Variables	Congenital group	Rheumatic group	Mitral prolapse
Age in years:			
Range	0.3-4.0	6-16	8-14
Mean	1.77	11.42	11
SD	1.30	3.17	3
Sex:			
Males	4 (40%)	8 (40%)	1(20%)
Females	6 (60%)	12 (60%)	4(80%)

Table 2: MRFPV in mild, moderate and severe MR (Assessed by 3D color Doppler):

MRPFV	MILD MR	moderate MR	Severe MR
Range	11-29	32-50	50-90
Mean+SD	20+9	41+9	70+20
P value	P1-2 <0.05*	P2-3 <0.05*	P1-3 <0.05*

FPV= mitral regurgitation flow propagation velocity, MR= mitral regurgitation.

Table 3: EROA, R vol & RF% in mild, moderate and severe MR (mean+SD) measured by 3D color Doppler:

3D color Doppler	MILD MR	moderate MR	Severe MR
EROA (cm2)	16+9	33+17	74+41
Rvol (cm3)	25+13	59+21	101+44
RF %	28+ 9	38+9	59+12

MR= mitral regurgitation .EROA= effective regurgitation orifice area, R vol= regurgitation volume, RF= regurgitation fraction.

DISCUSSION

Noninvasive quantification of mitral valve regurgitation is still a controversial issue despite intense investigations on this topic. The lack of a "Gold standard" for the clinical measurement of regurgitant volume is the major limitation of this clinical studies (5). Echocardiography with Doppler has emerged as the method of choice for the non-invasive detection and evaluation of the severity and etiology of mitral regurgitation. Several indexes have been developed to assess the severity of regurgitation using Color Doppler, Pulsed wave (PW) and Continuous wave (CW) Doppler. To date, the assessment of mitral valve regurgitation in clinical settings commonly has been based on the semi-quantitative evaluation of color flow Doppler information by 2D Doppler.

Color flow Doppler is widely used for the detection of mitral regurgitation. Many methods based on the size of regurgitant jets have been proposed for clinical quantification of mitral regurgitation by color Doppler (6, 7) These techniques provides visualization of the origin of the regurgitation jet and its width (VCD), the spatial orientation of the regurgitant jet area in the receiving chamber and, in cases of significant regurgitation, flow convergence into the regurgitant orifice. Experience has shown that attention to these three components of the regurgitation lesion by color Doppler significantly improves the overall accuracy of estimation and quantitation of the severity of regurgitation with color Doppler techniques. The size of the regurgitation jet by color Doppler and its temporal resolution however, are significantly affected by transducer frequency and instrument settings such as gain, output power, Nyquist limit, size and depth of the image sector (8).

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The cross-sectional area of the vena contracta represents a measure of the effective regurgitant orifice area, which is the narrowest area of actual flow. It is independent of flow rate and driving pressure for a fixed orifice (9). However, the vena contracta is considerably less sensitive to technical factors when high velocities are comprised and small errors in its measurement may lead to a large percent error and misclassification of the severity of regurgitation.

There are also many technical limitations related to optimal acquisition of flow convergence images and to quantitation of mitral regurgitant orifice area by PISA. Results vary widely for calculations at different aliasing velocities, and care must be taken to use the velocity at which the hemispheric formula applies best (10).

Pulse wave Doppler recordings of flow velocity can be combined with 2D measurements to derive flow rates and stroke volume (11). This method is simple in theory, briefly, stroke volume (SV) at any valve annulus is derived as the product of cross sectional area (CSA) and the velocity time integral (VTI) of flow at the annulus. Assumption of a circular geometry has worked well clinically for mitral valve. In the presence of regurgitation without any intracardiac shunt, the flow through the mitral valve is larger than other valves. The difference between the two represents the regurgitant volume (12). Regurgitant fraction is then derived as the regurgitant volume divided by the forward stroke volume through the regurgitant valve.

The most common errors encountered in determining these parameters are 1) failure to measure the valve annulus properly (Error is squared in the formula), 2) failure to trace the modal velocity (Brightest signal representing laminar flow) of the pulsed Doppler tracing and 3) failure to position the sample volume correctly, and with minimal angulation, at the level of the annulus. Furthermore, in the case of significant calcifications of the mitral annulus and valve, quantitation of flow at the mitral site is less accurate and more prone to errors (13).

With recent development of a much improved three-dimensional volumetric imaging, there have been efforts in trying to overcome these two-dimensional limitations using three-dimensional approaches (1).

Some studies have previously shown that color M-mode flow propagation towards the ventricle was a useful index for the assessment of left ventricular diastolic function (14). In case of MR, the pressure gradient between the ventricle and atrium generates the driving force causing flow to propagate from mitral orifice toward the left atrium. Thus, as the severity of regurgitant orifice increases, RFPV from high pressure left ventricle to low pressure left atrium increases. Onbasili, et al. found same correlation in aortic regurgitation (AR). In their study, the regurgitant flow velocity from high pressure aorta to low pressure left ventricle increased as the degree of AR increased (15).

The present study is the first one, to the best of our knowledge, in which color M-mode flow propagation velocity method has been used to evaluate mitral regurgitation in children. Color M-mode RFPV was found to be highly correlated with the MR degree quantitatively assessed using 3D color Doppler flow methods. RFPV measurements in this study provided very good cut points to discriminate mild and severe MR with very high sensitivity and specificity percentages.

In a previous study done by hashimoto, et al. (16) to assess the variables affecting flow propagation velocities in healthy children, The study group were two hundred and thirty five healthy children, mean age 7.4±5.4 years, 142 males and 93 females and flow propagation velocity was obtained from apical four chamber view and determined as the slope of aliasing velocity of early diastolic transmitral flow on the color M mode, their results showed that flow propagation velocity was less dependent on age, body size, heart rate and left ventricular dimension and no significant correlation was found between flow propagation velocity and ejection fraction.

Additionally Dufosse, et al. (17) to asses the reliability of jet area in correlation of left atrium area. Measurement and its correlation to angiographic data of mitral regurge, Eighteen patients with chronic rheumatic mitral regurgitation were aged between 7 and 19 years (Mean±SD) (12.69±3.47) and sixteen of them were performed cardiac catheterization within 24h. regurgitant jet area/LA ratio was calculate by color Doppler examination and regurgitation volume and fraction were calculated by angiography. They found that there was a good correlation between regurigation jet area and angiographic grade of mitral regurge ($P < 0.01$).

Moreover, Eren, et al. (18) previously evaluated mitral regurgitation using vena contracta, the study was done over Eighty seven patients with chronic mitral regurgitation, vean contracta <0.3 considered severe mitral regurgitation and in-between values considered moderate mitral regurgitation. The study concluded that vena contracta can differentiate accurately in between mild and severe mitral regurgitation (Sensitivity 95%) and also is a simple method to use.

COCLUSION

Mitral regurgitation flow propagation velocity is a simple, non invasive and reliable method for grading of mitral regurgitation showing high correlation to 3D color Doppler parameters.

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REFERENCES

1. Sugeng L, Chandra S, Lang RM. Three-dimensional echocardiography for assessment of mitral valve regurgitation. Curr Opin Cardiol 2009; 24(5):420-5.
2. Qi L, Yinan GE, Tian FW, et al. Quantitative analysis of mitral eccentric regurgitation jet based on real-time three-dimensional color Doppler flow images. Wavelet Anal Active Media Technol 2008:779-82.
3. Akdemir R, Ozhan H, Bulur S, et al. Color M-mode regurgitant flow propagation velocity: A new echocardiographic method for grading of mitral regurgitation. Echocardiography 2005; 22(9):713-22.
4. Marsan NA, Westenberg JJM, Ypenburg C, et al. Quantification of functional mitral regurgitation by real-time 3D echocardiography. Comparison with 3D velocity-encoded cardiac magnetic resonance. J Am Coll Cardiol Cardiovasc Imaging 2009; 2(11):1245-52.
5. Bolger AF, Eigler NL, Maurer G. Quantifying valvular regurgitation. Limitations and inherent assumptions of Doppler techniques. Circulation 1988; 78(5 Pt 1):1316-8.
6. Sahn DJ. Real-time two-dimensional Doppler echocardiographic flow mapping. Circulation 1985; 71(5):849-53.
7. Helmcke F, Nanda NC, Hsiung MC, et al. Color Doppler assessment of mitral regurgitation with orthogonal planes. Circulation 1987; 75(1):175-83.
8. Sahn DJ. Instrumentation and physical factors related to visualization of stenotic and regurgitant jets by Doppler color flow mapping. J Am Coll Cardiol 1988; 12(5):1354-65.
9. Baumgartner H, Schima H, Kuhn P. Value and limitations of proximal jet dimensions for the quantitation of valvular regurgitation: An in vitro study using Doppler flow imaging. J Am Soc Echocardiogr 1991; 4(1):57-66.
10. Schwammenthal E, Chen C, Giesler M, et al. New method for accurate calculation of regurgitant flow rate based on analysis of Doppler color flow maps of the proximal flow field. Validation in a canine model of mitral regurgitation with initial application in patients. J Am Coll Cardiol 1996; 27(1):161-72.
11. Lewis JF, Kuo LC, Nelson JG, et al. Pulsed Doppler echocardiographic determination of stroke volume and cardiac output: Clinical validation of two new methods using the apical window. Circulation 1984; 70(3):425-31.
12. Rokey R, Sterling LL, Zoghbi WA, et al. Determination of regurgitant fraction in isolated mitral or aortic regurgitation by pulsed Doppler two-dimensional echocardiography. J Am Coll Cardiol 1986; 7(6):1273-8.
13. Zoghbi WA, Enriquez Sarano M, Foster E, et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. J Am Soc Echocardiogr 2003; 16(7):777-802.
14. Garcia MJ, Smedira NG, Greenberg NL, et al. Color M-mode Doppler flow propagation velocity is a preload insensitive index of left ventricular relaxation: Animal and human validation. J Am Coll Cardiol 2000; 35(1):201-8.
15. Onbasili OA, Tekten T, Ceyhan C, et al. A new echocardiographic method for the assessment of the severity of aortic regurgitation: Color M-mode flow propagation velocity. J Am Soc Echocardiogr 2002; 15(12):1453-60.
16. Hashimoto I, Uese KI, Watanabe S, et al. Assessment of variables affecting flow propagation velocity of the left ventricle in healthy children. Pediatr Int 2007; 49(3):305-9.
17. Dufosse Hea. Qualification of Doppler color flow jet areas for mitral regurgitation in children. Am Soc Echocardiogr 2007; 90:209-12.
18. Eren M, Dağdeviren B, Bolca O, et al. The evaluation of the severity of mitral regurgitation using color Doppler echocardiographic methods. Anadolu Kardiyol Derg 2001; 1(2):90-7.