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Color M-mode Regurgitant Flow Propagation Velocity: A New Echocardiographic Method for Grading of Mitral Regurgitation

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Summary

The aim of this study was to evaluate the reliability of mitral regurgitation color M-mode regurgitant flow propagation velocity (RFPV) in grading mitral regurgitation (MR). This new transthoracic Doppler echocardiographic technique is easier and equally or more practical than qualitative and quantitative methods used to grade MR in patients both with normal and low left ventricular ejection fraction (LVEF). Color M-mode echocardiography allows resolution of regurgitant flow propagation along the echocardiography beam inside the left atrium. The characteristics of the velocity of this jet have not been studied in detail before. The present study compares the different qualitative and quantitative methods of MR grading with the RFPV. We prospectively 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. 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 3 methods was determined. The mean RFPV for mild, moderate and severe MR were 26.4±7 cm/s, 43.3±7 cm/s and 60.3±7.3, respectively ($p<0.001$). RFPV is highly sensitive and moderately specific in differentiating mild and severe MR from other subgroups. Sensitivity and specificity were 92.1-64.3% for mild and 100-68.5% for severe MR, respectively. Significant correlation was observed between pulse Doppler quantitative grades, RFPV, VC and RJA ($p<0.0001$, $r=.87$; $p<0.0001$, $r=-.84$; $p<0.0001$, $r=.76$, respectively). This results show that RFPV is a reliable and simple semi-quantitative new method that can be used for determining severity of MR. ***(Türk Kardiyol Dern Arş 2004; 32: 158-167)***

Key words: *Mitral regurgitation, color M-mode, flow propagation velocity.*

Özet

Mitral Yetersizliği Derecelendirilmesinde Yeni Bir Yöntem: Renkli M-mod Yetersizlik Akımı Yayılım Hızı

Bu çalışmanın amacı mitral yetersizliği derecelendirmesinde yeni bir yöntem olan renkli M-mod yetersizlik akımı yayılım hızı (YAYH) nın güvenilirliğini saptamaktır. Bu yeni yöntem düşük ejeksiyon fraksiyonlu hastalar dahil tüm hastalarda en az geleneksel kantitatif ve kalitatif yöntemler kadar güvenilir, hatta onlardan daha kolay uygulanabilir ve pratik bir yöntemdir. Renkli M-Mod Doppler ile sol atriyuma doğru yönlenen YAYH rezolüsyonu mümkün olmaktadır. Bu çalışmada, daha önce hakkında bilimsel bir veri bulunmayan bu yeni tekniğin tanısal duyarlılığı özgüllüğü incelenmekte ve geleneksel yöntemlerle karşılaştırılması yapılmaktadır. Kantitatif yöntemlerle derecelendirilmiş 10 hafif, 19 orta ve 23 ileri derecede mitral yetersizlikli toplam 52 ardışık hasta çalışmaya alındı. Mitral yetersizliği derecelendirilmesinde YAYH yöntemi; vena kontrakta çapı,

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regürjitan jet alanı ve kantitatif Doppler yöntemi ile karşılaştırıldı. Hafif, orta ve ileri derecede mitral yetersizliği için ortalama YAYH değerlerinin 26.4 ± 7 cm/s, 43.3 ± 7 cm/s ve 60.3 ± 7.3 cm/s olduğu saptandı. Hafif ve ileri derecede mitral yetersizliğinin diğer gruplardan ayrılmasında yeni yöntemin ileri derecede duyarlı ve orta derecede özgül olduğu görüldü. YAYH, hafif mitral yetersizliği için %92.1 duyarlı, %64.3 özgül; ileri derecede mitral yetersizliği için %100 duyarlı ve %68.5 özgüllüğe sahipti. Kantitatif Doppler, vena kontrakta ve regürjitan jet alanı yöntemleri ile anlamlı korelasyona sahipti ($p<0.0001$, $r=.87$; $p<0.0001$, $r=-.84$; $p<0.0001$, $r=.76$). Bu bulgular, YAYH yönteminin mitral yetersizliği derecelendirmesinde basitçe uygulanabilen güvenilir ve yarı-kantitatif bir yöntem olduğunu göstermektedir. ***(Türk Kardiyol Dern Arş 2004; 32: 158-167)***

Anahtar kelimeler: *Mitral yetersizliği, renkli M-mode Doppler, akım yayılma hızı*

Although evaluation of the severity of MR is difficult, it is important in the decision making of both medical therapy and timing of surgery. 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. The technique relies on the absolute or fractional left atrial area that is occupied by the systolic color Doppler regurgitant jet area when it is maximal (1). Although color flow imaging is sensitive, this technique is misleading with thin eccentric jets often underestimating severe MR and central jets often overestimating moderate MR(2). Therefore several other qualitative and quantitative echo Doppler methods are currently in use for assessment of MR: Methods defining width, size, and spread of the regurgitation jet in the left atrium in addition to methods related to continuous-wave Doppler jet signal density, pulmonary venous flow patterns, and dynamics of the left atrium are the most widely used qualitative methods for the evaluation of MR(3). These qualitative methods leads to high-degree interobserver and intraobserver variability. Quantitative methods (calculation of regurgitation volume (RV) and fraction (RF) and the measurement of orifice area) on the other hand are time consuming and highly operator dependent (4). There is an ongoing research to define a practical and reliable method that would be used to screen hemodynamically significant MR.

The severity of valvular regurgitation has an influence on the color M-mode Doppler flow propagation velocity directed to the chamber that regurgitant flow empties. Onbasili et. al. demonstrated the efficacy of color M-mode Doppler flow propagation of aortic regurgitation for quantitative evaluation (5). The purpose of this study was to evaluate the use of RFPV in measuring the severity of MR and compare its reliability with other quantitative and qualitative echocardiographic methods.

PATIENTS and METHODS

Patients: This study was performed prospectively in 52 patients referred for transthoracic echocardiography at Abant İzzet Baysal University, Düzce Faculty of Medicine between January 2003 and September 2003. The protocol of this study has been approved by ethical committee of scientific research programmes of Abant İzzet Baysal University, Düzce Faculty of Medicine.

Patients were included in the study if they had any degree MR by two-dimensional Doppler color flow imaging. Patients having moderate to severe degree aortic regurgitation or stenosis, significant mitral stenosis, acute myocardial infarction, a prosthetic valve or having any mitral surgical intervention were excluded. Presence of acute mitral regurgitation or heavy mitral annular calcification, presence of trace MR and rejection of study protocol were other criteria for exclusion.

Of the 60 patients initially enrolled, 8 (13%) were excluded because of inability of echocardiographic examination. Specific reasons for this inability were failure to visualize the vena contracta (n=5), failure to measure the diameter of the mitral annulus or left ventricular outflow tract (n=1), and inability to obtain a continuous-wave Doppler profile of the mitral regurgitant jet (n=2).

Mean age was 66.2 ± 12 years. The etiology of MR was rheumatic in 18 patients, ischeamic in 30 patients, prolapsed mitral valve in 2 patients, hypertrophic cardiomyopathy in one and dilated cardiomyopathy in one patient. Twenty five patients had isolated mitral regurgitation, while 27 had associated mild degree aortic regurgitation. Forty four patients were in sinus rhythm and 8 patients were in atrial fibrillation. Patients were divided into mild (10 patients), moderate (19 patients) and severe (23 patients) MR groups according to the quantitative Doppler evaluation.

Echocardiographic evaluation: All patients underwent a complete two-dimensional transthoracic echocardiographic and Doppler study in the left lateral decubitus position from multiple windows. All studies were performed with Vingmed Vivid-3 echocardiograph and a 2.5 MHz transducer. Echocardiographic measurements were performed according to the recommendations of the American Society of Echocardiography (6). Studies were recorded on compact disks for storage and review. Gain, depth, and sector angles were individualized for best measurement. In each echocardiographic method, measurements of at least three cardiac cycles were averaged in sinus rhythm and five in atrial fibrillation, respectively. One of the investigators (RA) performed all of the measurements and another (EE) served for interobserver variability.

Two-Dimensional echocardiographic calculations were obtained by parasternal long axis (PSL), apical three and four chamber views. Left ventricular ejection fraction was calculated by Teicholz formula. Left atrial ejection was calculated as the end-diastolic area - end-systolic area / end-diastolic area of the left atrium using apical three chamber views. Color flow imaging was performed from the parasternal long-axis, apical four-chamber, apical two-chamber, and apical long-axis views. Color gain was adjusted downward to the point at which background noise just disappeared. The narrowest sector angle that allowed best visualization of the MR jet was used to maximize color flow imaging frame rate. Nyquist velocity ranged from 39 to 70 cm/s, and the low-velocity cutoff ranged from 8 to 16 cm/s. A red-blue color map with variance was used on the Vingmed instrument, which displays the vena contracta in yellow.

In each patient, transducer angulations out of the standard echocardiographic planes was used to optimize visualization of the area of proximal flow acceleration, the vena contracta, and the downstream expansion of the jet. For each echocardiographic window, zoom mode was used to optimize visualization and measurement of the vena contracta. VCD was measured in each view from the systolic frame showing the largest diameter. To account for the possibility of nonsymmetrical orifices, a biplane VCD was calculated from the measurements made in two roughly orthogonal apical views. The jet direction was classified by use of the initial direction of the jet immediately behind the point of mitral leaflet coaptation. Thus, eccentric jets were in close contact with a mitral leaflet behind the regurgitant orifice, whereas central jets were initially directed into the center of the left atrium. To determine maximal regurgitant jet area in any view, the transducer was carefully panned to achieve the largest jet area. The outline of this jet was traced manually, and the area was calculated by use of software programming already incorporated into the equipment.

Mitral Regurgitation Color M-Mode Flow Propagation Velocity: Color M-mode Doppler measurements were obtained from apical five-chamber view or apical long axis view. M-mode cursor placement was attempted to be as parallel to mitral regurgitation flow obtained by color Doppler as possible. Before the color M-mode Doppler measurement, color scale of the equipment was adjusted for aliasing. The narrowest sector angle that allowed best visualization of the regugitant jet was used and color M-mode Doppler recording was performed. Adjustments were made to obtain the longest column of flow from the mitral valve to the left atrium. Color M-mode Doppler echocardiograms were recorded on a compact disk. Flow propagation velocity was measured as the slope of first aliasing velocity from the mitral valve to left atrial cavity (cm/sec). The slope of the color M-mode flow was described as the slope of a line hand-drawn along the color/no-color border (Figure 1A an B). Zoom mode was used to optimize visualization and measurement of the Color M-Mode Flow Propagation Velocity in some of the cases.

Quantitative Doppler Assessment: All patient were undertaken a quantitative Doppler evaluation. Patients were classified as having mild, moderate and severe MR according to effective regurgitant orifice area. As previously described, two-dimensional and Doppler echocardiography were used to make annular cross-sectional area and time velocity integral (TVI) measurements to calculate the mitral and aortic stroke volumes (7). The regurgitant volume

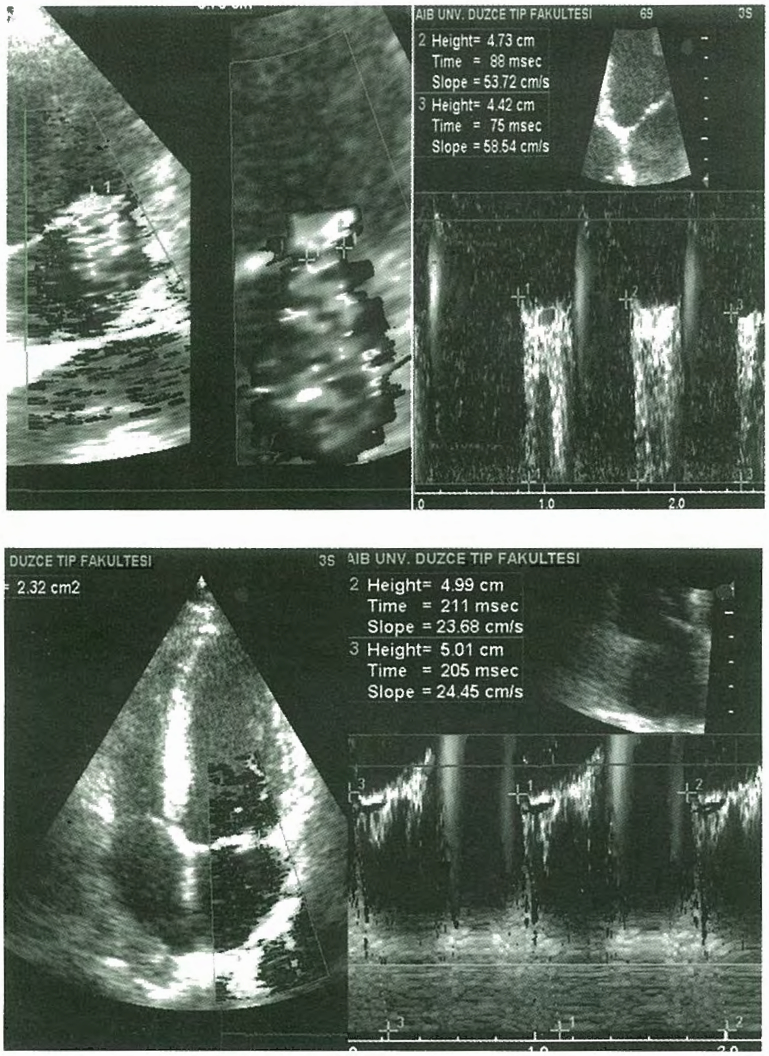

Figure 1A and 1B. Color M-mode recordings. A: severe mitral regurgitation (RJA: 10.2 cm^2, VC width: 0.75 cm, MR FPV=56 cm/sec); B: mild mitral regurgitation (RJA: 2.3 cm^2, FPV=24cm/sec). The flow propagation velocity (FPV) was measured as the slope of the first aliasing velocity from mitral valve to the left atrial cavity (blue line).

(Rvol), regurgitant fraction (RF), and effective regurgitant orifice (ERO) were calculated as follows: R. Vol. =(mitral-aortic) stroke volume; RF=RVol/mitral stroke volume; and ERO=RVol/regurgitant TVI, where regurgitant TVI is the TVI of the mitral regurgitant jet obtained by continuous-wave Doppler.

Interobserver and Intraobserver Variabilities: To determine the interobserver variability, MR RFPV, RJA, VCD measurements were obtained by a second observer in all patients without knowledge of previous measurements. To determine intraobserver variability, the same 52 patients were reanalyzed by the first observer two weeks later. Observer variability was defined as the absolute difference between two observations and expressed as a κ ratio.

Statistical Analyses: All values were given as mean ± standard deviation. Comparisons of MR RFPV, RJA and VCD with values among the three MR groups were performed by Student's t test. Correlations between MR FPV, RJA, VCD parameters and quantitative Doppler grading were obtained by using the Pearson correlation and linear regression analysis. P values < 0.05 were considered significant. Statistical Package for Social Sciences Software (SPSS 10.0 for windows) was used to calculate ROC analyses expressing sensitivity, specificity, positive predictive value, negative predictive value and cut points. Interobserver and intraobserver variability were calculated by Kappa analysis (Medcalc software, Mariakerke, Belgium).

RESULTS

The mean age was 66.2±12 years. Using effective regurgitant orifice area MR was graded as mild, moderate and severe, <0.30 cm^2, 0.30-0.39 cm^2 and >0.39 cm^2 respectively. Ten patients had mild, 19 had moderate and 23 had severe MR. Age, gender, left ventricular end-systolic diameter (LVSD), ejection fraction (EF), fractional shortening (FS); systolic and diastolic arterial blood pressure and heart rate variables were not statistically different among MR groups. Left ventricular end-diastolic diameters (LVDD) were significantly increased in moderate-severe MR group than the mild MR group ($p<0,05$). And also left atrial ejection fraction was decreased in severe and moderate groups as compared to mild group ($p<0.05$) (Table 1).

The mean RFPV, mitral regurgitant jet area and vena contracta widths were expressed in Table

Table 1. Clinical, Doppler and echocardiographic variables for the grades of mitral regurgitation

	Total	Mild MR	Moderate MR	Severe MR	P value
Number of patients (n)	52	10	19	23	
Age	66.2 ± 12.0	60.07 ± 14.7	69.0 ± 11.8	68.05 ± 7.86	0.072
Gender Male	35 (%67.3)	11 (%78.6)	14 (%66.7)	10 (%58.8)	0.505
Female	17 (%32.7)	3 (%21.4)	7 (%33.3)	7 (%41.2)	
LVSD (mm)	4.10 ± 0.93	3.63 ± 0.68	4.18 ± 0.99	4.37 ± 0.94	0.074
LVDD(mm)	5.62 ± 0.98	5.05 ± 0.92	5.73 ± 0.92	5.95 ± 0.96	0.030
EF (%)	54.0 ± 12.8	60.35 ± 11.3	51.90 ± 12.7	51.35 ± 12.88	0.092
LAEF (%)	52.7 ± 13.4	66.8 ± 8.8	51.1 ± 12.4	48.0 ± 11.9	<0.05
FS (%)	29.71 ± 8.40	33.50 ± 7.83	28.23 ± 8.26	28.41 ± 8.54	0.143
SABP (mmHg)	128.6 ± 10.3	131.1 ± 9.02	129.5 ± 10.8	125.6 ± 10.6	0.301
DABP (mmHg)	77.03 ± 8.05	78.57 ± 10.1	77.42 ± 6.98	75.29 ± 7.59	0.420
Heart rate (bpm)	71.69 ± 6.47	72.57 ± 6.19	72.19 ± 7.31	70.35 ± 5.71	0.583

**P=0.003 for mild to moderate and severe. P< 0.001 for severe to mild and moderate.*
(MR: mitral regurgitation, LVSD: left ventricle end-systolic diameter, LVDD: left ventricle end-diastolic diameter, EF: ejection fraction, FS: fractional shortening, SABP: systolic arterial blood pressure, DABP: diastolic arterial blood pressure)

Table 2. The mean RFPV, mitral regurgitant jet area and vena contracta width in groups that were graded by quantitative Doppler measurement

	Mild MR	Moderate MR	Severe MR	p; 1-2	p; 1-3	p; 2-3
RFPV (cm/s)	26.4 ± 7	43.3 ± 7.7	60.3 ± 7.3	p<0.001	p<0.001	p<0.001
RJA (cm^2)	6.04 ± 5.31	9.31 ± 5.47	15.58 ± 4.74	p<0.001	p<0.001	p<0.001
VC width (cm)	0.33 ± 0.18	0.51 ± 0.14	0.69 ± 0.13	p<0.001	p<0.001	p<0.01

(RFPV: color m-mode regurgitant flow propagation velocity, MR: mitral regurgitation, RJA: regurgitant jet area, VC: vena contracta)

2. All the three qualitative grading modalities showed significant differences between the three groups that were graded by quantitative Doppler measurement. The color-M mode flow propagation velocity; the new grading technique studied in this paper, was found to be very significant between the groups that were assessed with quantitative Doppler (p<0.001).

The mean values of RFPV were 26.4±7 cm/s, 43.3±7 cm/s and 60.3±7.3 respectively, in mild, moderate and severe MR groups, respectively (p<0.001) (Table 2). There was a high correlation between the grade of mitral regurgitation by quantitative Doppler analyses and the flow propagation velocity as measured by color M-mode Doppler recording (r:0,87). 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). Association between the left ventricular ejection fraction and RFPV was also evaluated. There was not any statistically significant association between LVEF and RFPV in mild, moderate and severe groups (p>0.05, Pearson Correlation using T-tailed test) when the patients grouped as mild, moderate and severe by quantitative echocardiograph. There was not any significant association between the left atrial

Table 3. RFPV (cm/sec) by color M-mode Doppler, RJA by color Doppler, VCD and their cut point values, sensitivities, specificities, positive and negative predictive values

	Patients grouped by Quantitative doppler	Cut points	Sensitivity	Specificity	(+) predictive value	(-) predictive value
MR RFPV	Mild from moderate and severe	≤ 30	94.74%	57.14%	85.71%	80.00%
	Severe from moderate and mild	≥ 50	94.12%	71.43%	61.54%	96.15%
MR RJA	Mild from moderate and severe	≤ 4	89.47%	57.14%	85.71%	80.0%
	Severe from moderate and mild	≥ 8	100%	62.96%	57.67%	100%
VCD	Mild from moderate and severe	≤ 0.3	97.37%	64.29%	88.10%	90.0%
	Severe from moderate and mild	≥ 0.7	52.94%	91.43%	75.0%	80.0%

(RFPV: color M-Mode regurgitant flow propagation velocity, MR: mitral regurgitation, RJA: regurgitant jet area, VCD: vena contracta diameter)

ejection fraction and the RFPV in mild and moderate groups (p>0.05). But there was a statistically significant reverse association between left atrial ejection fraction and RFPV in severe group between as assessed by Pearson Correlation (p<0.01 and r=-0.34).

By using 30 cm/sec and 50 cm/sec as cut points for the RFPV, a good discrimination for mild MR from moderate and severe regurgitation groups was obtained (Table 3). A 50 cm/sec cut point for RFPV provided a very good discrimination for severe MR from the mild and moderate MR groups (sensitivity 94.1%, specificity 71.4%, positive predictive value 61.5%, and negative predictive value 96%). However, 30 cm/sec as another cut point for the RFPV also permits a very good separation of mild MR from moderate and severe MR groups (sensitivity 92.1%, specificity 64.2%, positive predictive value 87.5%, and negative predictive value 75%).

RFPV, MR RJA and VC width values were correlated well with the quantitatively graded patients with MR with and without aortic valve pathology.

Interobserver and Intraobserver Variability: Interobserver and intraobserver variability was assessed by t test and as Kappa (κ) strength of agreement analyses (Table 4 and 5). κ were within very good limits for both intra and interobserver variability for RFPV.

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 (8). Echocardiography with Doppler has emerged as the method of choice

Table 4. The comparison of vena contracta width and RFPV measurements between observers and in the same observer after two weeks

	mean ± SD	p; 1-2	p; 1-3	p; 2-3
VCD^1 (cm) (1st observer)	0.52 ± 0.20	p>0.05	p>0.05	p>0.05
VCD^2 (cm) (2nd observer)	0.53 ± 0.19			
VCD^3 (cm) (2nd week)	0.53 ± 0.18			
RFPV ^{1} (cm/s) (1 st observer)	46.17 ± 14.72			
RFPV ^{2} (cm/s) (2nd observer)	48.00 ± 16.34			
RFPV ^{3} (cm/s) (2nd week)	47.46 ± 16.45			

(RFPV: color M-Mode regurgitant flow propagation velocity, VCD: vena contracta diameter)

Table 5. Kappa (κ) values for interobserver and intraobserver variabilities

	Intraobserver variability (κ)	Interobserver variability (κ)
RFPV (cm/s)	0.808±0.109	0.824±0.110
RJA (cm^2)	0.825±0.154	0.703±0.158
VCD (cm)	0.742±0.112	0.758±0.115

(κ is 0 when there is no agreement better than chance; κ is negative when agreement is worse than chance. Strength of agreement is poor when κ < 0.20, fair if κ is in between 0.21 - 0.40, moderate if κ is in between 0.41 - 0.60, good if κ is in between 0.61 - 0.80 and very good if between κ is in between 0.81 - 1.00. RFPV: Color M-Mode regurgitant flow propagation velocity, RJA: mitral regurgitant jet area, VCD: vena contracta diameter)

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.

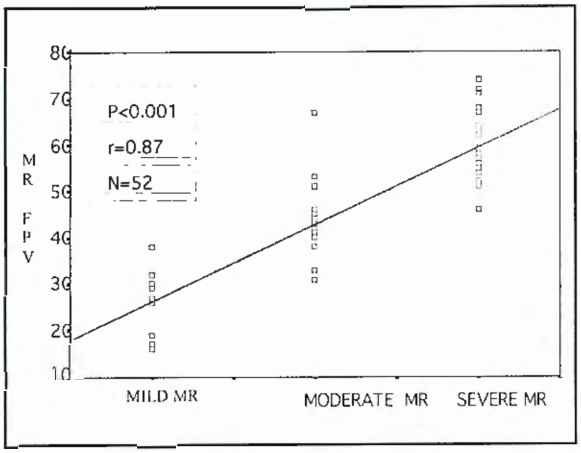

Figure 2. Linear regression analysis of MR FPV values (cm/sec) measured by color M-mode Doppler from Quantitatively graded MR severity. Axis X -Quantitatively graded MR stages

Axis Y - MR FPV (cm/sec) measured by color M-Mode Doppler.

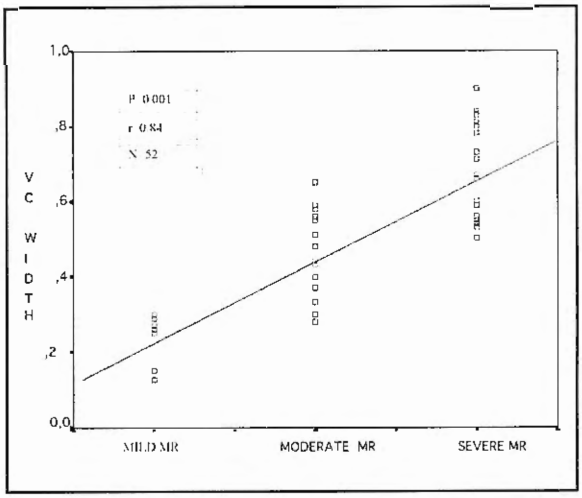

Figure 3. Linear regression analysis of VCD values (cm) measured by color Doppler from quantitatively graded MR severity. Axis X - Quantitatively graded MR stages. Axis Y - VCD (cm) measured by color Doppler

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 (9,10). 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 (11).

Visualization of the regurgitant jet area in the receiving chamber can provide a rapid screening of the presence of the regurgitant jet and a semi-quantitative assessment of its severity, but numerous technical, physiologic and anatomic factors affect the size of the regurgitant area and therefore alter its accuracy as an index of regurgitation severity (11).

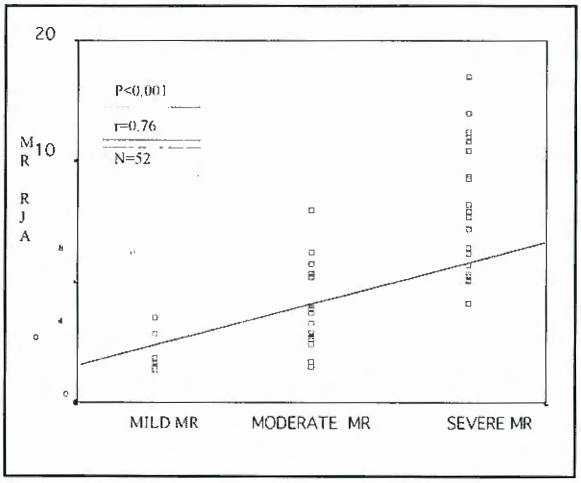

Figure 4. Linear regression analysis of MR RJA values (cm^2) measured by color Doppler mapping from quantitatively graded MR severity. Axis X - Quantitatively graded MR stages. Axis Y - MR RJA (cm^2) measured by color Doppler

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 (12). 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 (13).

Pulse wave Doppler recordings of flow velocity can be combined with 2D measurements to derive flow rates and stroke volume (14). 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 (15).

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 (16).

Recently, a new method for quantitative approach of MR had been introduced. This approach using three-dimensional Doppler revealed origin, direction, and spatial spreading of complex jet geometry and also capable of quantifying asymmetrical jets. This technique needs a sophisticated state of the art echocardiograph and software. Also, it uses video signals, which prevent a separate visualization of cardiac structures and intracardiac flow. Another limitation is the inability to perform quantitative analysis of single-flow jet components and the differentiation of slow velocities from turbulent flows (17).

The measurement of jet width at its origin has been suggested for assessing the severity of mitral regurgitation by transesophageal color Doppler. However, conventional 2D assessment of eccentric regurgitant jets fails to estimate the severity of mitral regurgitation (18).

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 [19]. 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. Onbaşılı 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 [5].

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 semi-quantitatively. Color M-mode RFPV was found to be highly correlated with the MR degree quantitatively assessed using pulsed Doppler flow methods.

In this study, RFPV measurements of mitral regurgitant flow performed easily in 52 of 60 patients (87%). RFPV measurements in this study provided very good cut points to discriminate mild and severe MR with very high sensitivity and specificity percentages.

Limitations of the study: The absence of a gold standard for quantitative assessment of mitral regurgitation is a major limitation of all clinical studies on this topic. Regurgitant fraction obtained by pulsed Doppler were used in our study for comparing the quantitative assessments of MR. Although these methods have been used in most clinical studies on the subject [18,20] they do not provide a reliable quantification of mitral regurgitant volume (RV) [17].

Even the very slightest alterations in the calculation of either stroke volume or cardiac output will cause significant errors in the calculations of RV. Also, atrial fibrillation or mitral regurgitation will adversely affect the predictive accuracy of the calculations for RV. Also RFPV is dependent on the compliance of left atrium , the systemic and pulmonary vascular resistance, loading conditions, heart rate and other associated valvular lesions. These factors, affecting the pressure drop across the mitral valve, could have effects on RFPV measurements.

The lack of left ventriculography is an other limitation of the study, but ethical committee did not approve ventriculography in all mild and moderate groups.

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