

Assessment of Doppler Echocardiography in Minimal Mitral Regurgitation: A Comparative Study with Ventriculography

Cemal SAĞ, MD, Ata KIRILMAZ, MD, Hasan Fehmi TÖRE, MD, Nadir BARINDIK, MD, Tuncay ALTUN, MD, Hürkan KURŞAKLIOĞLU, MD, Mehmet UZUN, MD, Deniz DEMİRKAN, MD

Gülhane Military Medical Academy, Department of Cardiology, Ankara, Turkey

MINİMAL MİTRAL YETMEZLİKTE DOPPLER EKOKARDİYOĞRAFİNİN DEĞERLENDİRİLMESİ: VENTRİKÜLOGRAFI İLE KARŞILAŞTIRILMALI BİR ÇALIŞMA

Bu çalışma minimal mitral yetmezlik (MY) haricinde sağlıklı kalbi olan kişilerde renkli Doppler ekokardiyografik parametrelerin değerlendirilmesi için yapılmıştır. Çalışma vakaları, 5 aylık bir periyotta, hasta şikayeti ve fizik muayene sonucunda ekokardiyografi yapılan 2500 genç erkek vakadan seçildi. Sol ventrikülografi yapılan vakalar, anjiyografik MY varlığında grup-1 (n=30), yokluğunda grup-2 (n=30) olarak sınıflandırıldı. Grup-1'deki hastalar "gerçek MY", grup-2'deki vakalar ise "fizyolojik" olarak adlandırıldı. Fizyolojik ve gerçek mitral yetmezliğin Doppler ekokardiyografik değişkenleri birbirini ile karşılaştırıldı. Aşağıdaki ekokardiyografik değişkenler grup-1 ve grup-2 arasında farklı saptandı. 1) parasternal uzun eksende maksimum MY süresilortalama sistol süresi (sırasıyla 0.710 ± 0.244 ve 0.430 ± 0.268 , $p < 0.001$), 2) apikal 4 odada maksimum MY süresilortalama sistol süresi (sırasıyla 0.550 ± 0.361 ve 0.317 ± 0.272 , $p = 0.007$) 3) parasternal uzun eksende rejürjitan akım pik hızı (sırasıyla 180 ± 77 ve 120 ± 69 cm/sn, $p = 0.003$), 4) parasternal uzun eksende rejürjitan jet alanı (sırasıyla 0.813 ± 0.561 ve 0.411 ± 0.431 , $p = 0.007$).

Parasternal uzun eksende maksimum MY süresilortalama sistol süresi ≥ 0.6 , rejürjitan jet alanı ≥ 0.4 cm² ve rejürjitan akım pik velosite jet alanı ≥ 130 cm/sn olmasının gerçek MY için prediktif değeri sırası ile % 76, % 67 ve % 63 saptanmıştır.

Anahtar kelimeler: Minimal mitral yetmezlik, Doppler ekokardiyografi, renkli Doppler ekokardiyografi, ventrikülografi.

Many investigators have argued that Doppler is too sensitive in mitral regurgitation (MR), frequently detecting small amounts of insufficiency in otherwise normal hearts. Reported prevalence of MR in normal

subjects varies considerably (1-5). Differences in Doppler techniques, definitions of regurgitation, age, and racial body habitus may partly explain this discrepancy. The hemodynamic significance, if any, of this minimal or trace mitral regurgitation remains uncertain. To what extent the Doppler examination of this flow patterns reflect the "true mitral regurgitation" is also an unknown issue. To disclose hemodynamic uncertainty and assess the role of Doppler echocardiography in the evaluation of minimal MR, we performed left ventriculography in subjects founded to have minimal MR by Doppler echocardiography.

MATERIALS and METHODS

Cases: Study cases have been selected during a five-month period among 2500 young male admittants who were recruited for the army. All subjects with minimal MR and otherwise structurally normal heart by Doppler echocardiographic evaluation and who signed the informed consent underwent cardiac catheterization and left ventriculography for confirmation of MR. Echocardiography was indicated on the basis of subjects' complaints and upon physical examination. Subjects with poor acoustic window, multiple premature ventricular contractions and/or catheter-induced MR at the time of ventriculography making the quantification of MR impossible, and with concomitant valvular heart disease were excluded from the study. Patients with any systemic disease including hypertension and mitral valve prolapse fulfilling Perloff's criteria (6) or with systolic displacement into the left atrium in the parasternal views were also excluded. Thus, the study consisted of 60 subjects. Group-1 comprised 30 patients who had angiographically confirmed MR and represented the patients with hemodynamically important and true MR. There was no evidence of MR by ventriculography in the remaining 30 patients and the Doppler parameters are stated to represent physiological MR and accepted to be hemodynamically unimportant phenomenon. All subjects were men, ranging in age from 19 to 34 years (mean 22 ± 2.5).

Echocardiography: Doppler examinations were performed

Received May 23, revision accepted November 10, 1996
Correspondent: Dr. Ata KIRILMAZ Gülhane Askeri Tıp Akademisi, Kardiyoloji Anabilim Dalı 06018 Etlik, Ankara, TURKEY.
Phone: 90-312-325 12 11 ext. 13 73 90-312-353 29 89 (home)
Fax: 90-312 77 78

med with commercially available system, Hewlett Packard Sonos 2500 equipped with 2.5 MHz transducer. All echocardiographic measurements were performed in a single session. The median interval between angiography and Doppler examination was 3 days (range 0 to 8 days).

Color Doppler Echocardiography: Color image mode was set in velocity mode. Flow directed toward and away the transducer was coded red and blue, respectively. Maximum velocity of color bar display was adjusted until a good qualitative color images were obtained. Doppler color gain was first turned down completely and then increased very gradually until the static background noise barely appeared. The size of the color sampling and black and white display were reduced as much as possible to enhance the frame rate and thus the color image quality. The wall filter was set to 400 Hz. Parasternal long axis and apical four-chamber views were used to trace the jet of MR. Jet area $>2.1 \text{ cm}^2$ was considered exclusion criteria arbitrarily.

Pulsed and continuous Doppler study: Systolic time was measured as the interval between the closing and the opening of the mitral leaflets. Duration of regurgitant flow was calculated just above at the level of 90 cm/second. Measurements were repeated at least three times in both views and the mean and the maximal value of the duration of regurgitant flow were used in the analyses. To minimize the effect of different RR intervals, the mean systolic time interval was used as a denominator and the ratio of the mean duration of MR/mean systolic time interval (meanMRd/MSTI) and the ratio of the maximal duration of MR/mean systolic time interval (max.MRd/MSTI) were used as variables in both views. Mitral valve regurgitation was defined as minimal or mild when regurgitant spectral signals were confined to just below the mitral valve or in the proximal one fourth of the left atrial chamber. Cases exceeding this grade were not included in this study.

In addition to pulsed Doppler operation, examination by continuous-wave Doppler technique and a nonimaging transducer were used where blood flow velocities exceeded the Nyquist limit of the pulsed Doppler system. Maximum velocity of the regurgitant flow in both views was another variable.

Cardiac catheterization and left ventriculography: Left-sided heart catheterization was performed by the femoral approach with maximal 40 ml of iohexol (Omnipaque 350mg I/ml) injected at a rate of 15 ml/sec. adjusted to the weight and intraventricular diameters both in a 30-degree right anterior oblique (RAO) and a 45-to 60-degree left anterior oblique (LAO) view. Pressures were obtained with a micromanometer-tipped catheter and recorded to determine pressure difference after ventriculography. Mitral regurgitation was graded between 1+ and 4+ as described by Grossman (7). Regurgitation that is 1+ essentially clears with each beat and never opacifies the entire left atrium. When regurgitation is 2+, it does not clear with one beat and does opacify the entire left atrium after several beats; however opacification does not equal to that of the left ventricle. Two cardiologists graded the degree of mitral regurgitation independently. Decision of a third experienced cardiologist was accepted in the presence of conflict. No patient presented MR above grade 2+.

RESULTS

This study is unique for its feature of comparing transthoracic echocardiographic minimal MR with catheterization findings. Ventriculography was performed to dichotomize the cases into true and physiologic MR groups.

Among the echocardiographic parameters compared between group-1 (n=30) and group-2 (n=30), the most significant differences were found in the following parameters; 1) the meanMRd/MSTI and the max.MRd/MSTI in parasternal long axis view ($p<0.0001$ and $p<0.0001$, respectively), 2) the meanMRd/MSTI and the max. MRd/MSTI in apical four chamber view ($p=0.027$ and $p=0.007$, respectively), 3) regurgitant jet area in parasternal long axis ($p=0.007$), 4) the peak velocity of the regurgitant flow in parasternal long axis ($p=0.003$) (values in number are depicted in Table-1). One patient in group-1 and 5 cases in group-2 revealed no regurgitant flow in parasternal long axis. The patient in group-1 had a peak velocity of 154 cm/sec, but no regurgitant area in parasternal long axis. In apical four-chamber, this patient revealed relatively small jet area (0.084 cm^2), but the ratio of max. MRd/MSTI was 0.938 with a peak velocity of 155 cm/sec. Two of the 5 cases with no pulsed-Doppler regurgitation in parasternal long axis in group-2 revealed only minute amount of jet area (0.087 and 0.037 cm^2 in parasternal long axis, 0.223 and 0.197 cm^2 in apical four-chamber) otherwise normal pulsed and continuous Doppler evaluation. In other words, regurgitant jet areas measured were the only inclusion criteria for these cases. In the remaining 3 cases, parasternal long axis revealed jet area within range of 0.007 to 0.344 cm^2 . In apical four-chamber view of these three cases, peak velocities were 96, 100, and 120 cm/sec., jet areas were 0.414, 0.595, and 0.540 cm^2 , and max. MRd/MSTI were 0.257, 0.231, and 0.571, respectively.

Apical four-chamber view revealed no pulsed or continuous Doppler spectrum in 6 patients in group-1. Four of these patients revealed jet areas between 0.125 and 0.274 cm^2 , while the other 2 patients revealed no regurgitant color Doppler in apical four chamber. Parasternal long axis view in these 6 patients was highly suggestive of true MR and the jet area was between 0.228 and 1.42 cm^2 (mean 0.562

Table 1. Comparison of the echocardiographic parameters of group-1 and 2.

ECHOCARDIOGRAPHIC VARIABLES	GROUP-1 Mitral regurgitation in ventriculography n=30	GROUP-2 No mitral regurgitation in ventriculography n=30	P value
AGE (years)	21±2.7	22±2.3	Ns
PARASTERNAL LONG AXIS VIEW			
MeanMRd/MSTI	0.65±0.229	0.382±0.233	<0.0001
Max.MRd/MSTI	0.710±0.244	0.430±0.268	<0.0001
Regurgitant area (cm ²)	0.813±0.651	0.411±0.431	=0.007
Regurgitant peak velocity (cm/sec)	180±77	120±69	=0.003
APICAL FOUR CHAMBER			
MeanMRd/MSTI	0.457±0.300	0.293±0.256	=0.027
Max.MRd/MSTI	0.550±0.361	0.317±0.272	=0.007
Regurgitant jet area (cm ²)	0.570±0.567	0.391±0.331	NS
Regurgitant peak velocity (cm/sec)	128±83	97±91	NS

NS: Not statistically significant. MeanMRd/MSTI: The ratio of the mean duration of mitral regurgitation to mean systolic time interval, max.MRd/MSTI: The ratio of the maximum duration of mitral regurgitation to mean systolic time interval.

cm²), peak velocity between 125 and 232 cm/sec. (mean 158 cm/sec.), and max.MRd/MSTI between 0.421 and 0.877 (mean 0.633).

Pulsed and continuous Doppler in apical four-chamber view was not suggestive in 10 cases of group-2. Regurgitant jet area in this echocardiographic view was between 0 and 0.459 cm² (mean 0.230±0.129 cm²). Echocardiographic variables in parasternal long axis were highly suggestive of physiologic regurgitation. Jet area was 0.260±0.167 cm², max.MRd/MSTI 0.283±0.157.

The regurgitant jet area in apical four-chamber view was not significantly different between group-1 and group-2 (p>0.05). The regurgitant jet was not detected in 4 patients in apical four chamber and in 2 patients in parasternal long axis in group-1. According to the logistic regression analysis of the data, the max.MRd/MSTI in parasternal long axis ≥0.6 has a predictive value of 73% in dichotomizing the cases into true and physiologic MR. Regurgitant jet area ≥0.4 cm² in parasternal long axis has a predictive value of 67% in diagnosing true MR and 63% in physiologic MR. In parasternal long axis, regurgitant peak velocity ≥ 130 cm/sec. has a predictive value of 63% in detecting physiologic MR and peak velocity ≥130 cm/sec has a predictive value of 76% in detecting true MR.

Nine patients in group-1 had 2+ MR and the remaining had 1+ MR in left ventriculography. Peak MR velocity in apical four chamber view was the single and statistically the most important (p=0.013) variable in comparison of patients with 1+ and 2+ MR to each other (Table-2). The regurgitant area was not indicative of the degree of MR in group-2.

DISCUSSION

Valvular regurgitation occurs not uncommonly in patients with structurally normal hearts referred for echocardiographic examination. Mitral regurgitation is the most common and in the majority of cases, the severity of regurgitation evaluated semiquantitatively by Doppler echocardiography is minimal (3).

Choong et al (3) reported the prevalence of mitral regurgitation as 19% by Doppler examination among 867 subjects with no structural abnormality on 2D echocardiograms. In nearly all records (98%) with MR, there was only either trace or grade 1+ regurgitation. As pointed out in the study by Yoshida and colleagues (5), MR could be detected in 43% of individuals within third decade. Regurgitant area in healthy subjects (in group-2) in our study ranged from 0.0 to 2.1 cm², rather high in comparison with those of Yoshida. This can be attributed to the selection of

Table 2. Comparison of the echocardiographic parameters of the patients with +1 and +2 mitral regurgitation in group-1.

ECHOCARDIOGRAPHIC VARIABLES	Patients with +1 Mitral regurgitation in ventriculography n=21	Patients with +2 mitral regurgitation in ventriculography n=9	P value
AGE (years)	22±3	21±1	NS
PARASTERNAL LONG AXIS VIEW			
MeanMRd/MSTI	0.649±0.256	0.654±0.162	NS
Max.MRd/MSTI	0.712±0.276	0.704±0.157	NS
Regurgitant jet area (cm ²)	0.753±0.675	0.920±0.514	NS
Regurgitant peak velocity (cm/sec)	170±76	203±79	NS
APICAL FOUR CHAMBER			
MeanMRd/MSTI	0.400±0.321	0.580±0.211	NS
Max.MRd/MSTI	0.496±0.401	0.676±0.215	NS
Regurgitant jet area (cm ²)	0.515±0.598	0.698±0.497	NS
Regurgitant peak velocity (cm/sec)	105±85	183±44	0.013

our patients, as they might present echocardiographic, electrocardiographic and/or physical variabilities.

Table-1 shows that parasternal long axis is more sensitive than apical four chamber in detecting true MR. This can be partly attributed to more distance between probe and pulsed sample volume in apical four chamber.

Regurgitant jet area has not been correlated well with the angiographic severity of MR (8). Area of regurgitant jet in our groups was also unconfirmative to dichotomize the cases into one of the groups (except of parasternal long axis) or to grade the severity of MR in group-1.

With Doppler echocardiography, regurgitant signals were not detected in 5 patients in group-1 and 9 subjects in group-2 (six in apical four chamber and 5 in parasternal long axis), although color Doppler echocardiography revealed regurgitant color. This may be due to very localized small jets and failure to position the sample volume in the jet as well as the time consumed.

A previous study states that the total regurgitant area including the surrounding swirling flow in transthoracic studies gives the best correlations with left ventriculography in MR (9). However the central aliased core of the regurgitant jet with the mosaic pattern was traced as the regurgitant area in this study.

But our cases present minimal regurgitant jet area and represent a different group, namely minimal regurgitant jet, in comparison with those of the above mentioned study.

In conclusion, in parasternal long axis the max. MRd/MSTI ≥ 0.6 , regurgitant jet area ≥ 0.4 cm², regurgitant peak velocity ≥ 130 cm/sec. dichotomize the cases into true, otherwise physiologic MR. We think long term follow-up of these patients is essential and in the evaluation of this pathology, different echocardiographic systems and perspectives should be used (10).

Limitations: Excessively low gain would result in underestimation of MR because of elimination of lower velocity signals. An excessively high gain would clutter the image with static "noise," making it difficult to visualize the outline of MR. Therefore it is important to optimize the gain settings when performing the color Doppler examination. Small changes in transducer angulation and motion may produce marked variations in the size of the regurgitant jet. This made it mandatory for the examiner to move and angle the transducer slightly in various directions when examining the flow patterns in each of the two standard planes. But the angle between the septal plane and Doppler line was not over 20 degrees.

Dimensions and size of the regurgitant jet signals as well as peak velocity are related not only to the size

of the defect in the valve but also to the pressure gradient across the valve. But velocities obtained for MR were in the range of one or two meters per second in our study. This may partly be explained by the small amount of regurgitant volume and difficulty to keep the sample volume on jet flow. Our subjects were also free of any disease which could cause increment in intraventricular pressure.

Possible misleading grouping of cases because of true MR missed in left ventriculography was prevented to most extent by excluding the patients with eccentric MR jets which was the most common reason responsible for the discrepancy between Doppler techniques and ventriculography.

REFERENCES

1. Akasaka T, Yoshikawa J, Yoshida K, et al: Age-related valvular regurgitation: a study by pulsed Doppler echocardiography. *Circulation* 1987; 76: 262
2. Kostucki W, Vandebosche J, Friart A, Englert M: Pulsed Doppler regurgitant flow patterns of normal valves. *Am J Cardiol* 1986; 58: 309
3. Choong CY, Abascal VM, Weyman J, et al: Prevalence of valvular regurgitation by Doppler echocardiography in patients with structurally normal hearts by two-dimensional echocardiography. *Am Heart J* 1989; 117: 636-42
4. Yock PG, Schnittger I, Ropp RL: Is continuous wave Doppler too sensitive in diagnosing pathologic valvular regurgitation [Abstract]. *Circulation* 1984; 70 (suppl II): II-381
5. Yoshida K, Yoshikawa J, Shakudo M, et al: Color Doppler evaluation of valvular regurgitation in normal subjects. *Circulation* 1988; 78: 840-7
6. Perloff JK, Child JS, Edwards JE: New guidelines for the clinical diagnosis of mitral valve prolapse. *Am J Cardiol* 1986; 57: 1124
7. Grossman W: Profiles in valvular heart disease in Grossman W, Baim DS (eds). *Cardiac Catheterization, Angiography and Intervention*. 4th ed, Philadelphia: Lea and Febiger, 1991: 557-617
8. Helmcke F, Nanda NC, Hsiung MC, et al: Color Doppler assessment of mitral regurgitation with orthogonal planes. *Circulation* 1987; 75: 175-83
9. Castello R, Lenzen P, Aguirre F, Labovitz A: Variability in the quantitation of mitral regurgitation by Doppler color flow mapping: comparison of transthoracic and transesophageal studies. *J Am Coll Cardiol* 1992; 20: 433-8
10. Stevenson JG. Two-dimensional color Doppler estimation of the severity of atrioventricular valve regurgitation: Important effects of instrument gain setting, pulse repetition frequency, and carrier frequency. *J Am Soc Echocardiogr* 1989; 2: 1-10