Assessment of Mitral Stenosis by Doppler Echocardiography
− Influence of Atrial Fibrillation on Doppler Pressure Half-Time −

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승모판 협착증에서 심방세동이 승모판혈류 Doppler 심초음파도의 Pressure Half-Time에 미치는 영향

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국문초록

승모판 협착증에서 Doppler 심초음파도로 승모판구 면적을 측정할때 주로 승모판혈류의 pressure half-time(PHT) 법을 이용하고 있다.

심방세동이 동반된 경우에는 혈류의 최대속도나 경사도등이 변화되어 이방법으로 승모판구 면적을 측정하는데 제한점이 있는것으로 알려지고있으나 이에 대한 연구는 드문 실정이다. 이에 저자들은 Doppler 심초음파와 이면성 심초음파도를 검사한 203례의 승모판 협착증 환자를 대상으로 하여 승모판구 면적을 Doppler 심초음파도로 측정할때 심방세동이 이에 미치는 영향에 대해 분석하여 다음과 같은 결과를 얻었다. 전체환자중 정상동조율인 환자는 63례, 심방세동이 동반된 환자는 140례 이었다. 승모판 폐쇄부전(MR) 또는 대동맥판 폐쇄부전(AR)의 동반에 따라 4군으로 분류하였다. 전체환자에서 정상동조율군, 심방 세동군 양군 모두 Doppler 심초음파도의 승모판구 면적 지표인 PHT, 평균 압력차, 최대 압력차 및 최대 혈류속도는 이면성 심초음파의 승모판구 면적(2DE-MVA)와 유의한 상관관계가 있었다(P<0.005). 제1군은 승모판 협착증만 있는 90례의 환자이었다. 정상 동조율군 32례, 심방 세동군 58례로 양군 모두 Doppler 심초음파도의 승모판구 면적 지표와 2DE-MVA 사이에 유의한 상관관계가 있다(P<0.005). 제2군은 MR이 동반된 45례 환자이었다. 정상동조율군 13례, 심방세동군 32례로 양군 모두 Doppler 심초음파도의 승모판구 면적지표와 2DE-MVA 사이에 유의한 상관관계가 있었다(P<0.005). 제3군은 AR이 동반되있는 54례 환자 이었다. 정상동조군 15례, 심방세동군 39례 이었다. 양군모두 PHT와 2DE-MVA사이에 유의한 상관관계가 있었다(P<0.005). 제4군은 MR과 AR이 함께있는 14례로 이중 11례의 심방세동군이 PHT와 2DE-MVA 사이에 유의한 상관관계가 있었다(P<0.005).

이상의 결과로 MR또는 AR이 동반되있는 승모판 협착증 환자에서 승모판구 면적을 승모판 혈류의 PHT를 이용하여 측정할때 심방세동에 의해 영향을 받지 않을것으로 생각되었다.

= Abstract =

Atrial fibrillation in mitral stenosis(MS) may be cause of error in calculation of mitral valve area (MVA) by Doppler derived pressure half-time (PHT) method. This is due to changes of peak velocity and diastolic slope in mitral inflow Doppler spectrum in cases of assoociated with atrial fibrillation. However, few data exist regarding the effect of atrial fibrillation on the validity of this method. Two hundreds and three patients with mitral stenosis were studied by Doppler echocardiography and two-dimensional echocardiography(2DE) to assess whether atrial fibrillation affected the calculation of MVA.

Total patients was divided into four groups according to the accompanied mitral or aortic regurgitation. Ninety patients had mitral stenosis only (group 1), 45 patients were combined with mitral regurgitation(group 2), 54 patients were combined with aortic regurgitation(group 3) and 14 patients were combined with both mitral and aortic regurgitation(group 4). And then, each group was divided into sinus rhythm subgroup and atrial fibrillation subgroup respectively.

In total patients, Doppler echocardiographic indices(pressure half-time, mean pressure gradient, peak pressure gradient and peak velocity) were correlated significantly with 2DE-MVA in both patients with sinus rhythm and patients with atrial fibrillation($P<0.005$). In group 1 patients, Doppler echocardiographic indices were significantly correlated with 2DE-MVA in both patients with sinus rhythm and patients with atrial fibrillation($P<0.005$). In group 2 patients, these Doppler derived indices were significantly correlated with 2DE-MVA in both patients with sinuns rhythm and patients with atrial fibrillation($P<0.005$). In group 3 patients, only pressure half-time was significantly correlated with 2DE-MVA in both patients with sinus rhythm and patients with atrial fibrillation($P<0$.

005). In group 4 patients, pressure half-time was significantly correlated in patients with atrial fibrillation($P<0.005$).

Therefore, Doppler echocardiography can estimates mitral valve area in patients with mitral stenosis associated with mitral and aortic regurgitation regardless of presence of the atrial fibrillation.

KEY WORDS : Mitral stenosis · Pressure half-time method · Atrial fibrillation.

INTRODUCTION

Doppler echocardiography has been used to quantitate the severity of mitral stenosis. Mitral stenosis causes a high diastolic velocity which usually exceeds 1.5 m/sec and decrease in diastolic slope. Since initial work of Hatle et al[1], the pressure half-time(PHT) method has been used widely[2-8]. The pressure gradient across the mitral valve can be measured with Doppler echocardiography using the modified Bernoulli equation[9,10].

The biphasic quality of the mitral diastolic spectrum is absent in patients with atrial fibrillation due to the loss of effective atrial contraction. The appearence of atrial fibrillation in patients with mitral stenosis is frequantly associated with clinical deterioration. The occurance of atrial fibrillation induces some changes in Doppler spectrum. First of all, peak velocity will be changed. The longer RR interval, the higher peak velocity. The shorter RR interval, the lower peak velocity. Therefore these beat to beat variation due to atrial fibrillation makes difficulty to determine which is true peak velocity. Next, the diastolic slope or the rate of decrease in diastolic flow following the initial peak velocity can be changed from beat to beat in cases of atrial fibrillation. Therefore pressure half-time, or the time it takes for the initial pressure to drop by half[9] can be changed.

To test whether mitral valve orifice area which is estimated from dividing 220 by the pressure half-

time will be affected or not in the presence of atrial fibrillation, 203 patients with mitral stenosis were studied by Doppler echocardiography and two-dimensional echocardiography.

SUBJECTS AND METHODS

Two hundreds and three patients with mitral stenosis were included in this study. 63 patients were in sinus rhythm and 140 patients were in atrial fibrillation.

Total study popualtion was divided into 4 groups with or without regurgitations. Group 1 was consisted of 90 patients who had mitral stenosis(MS) only. Group 2 was consisted of 45 patients who had mitral stenosis and mitral regurgitaion(MR). Group 3 was consisted of 54 patients who had mitral stenosis and aortic regurgitation(AR). Group 4 was consisted of 14 patients who had mitral stenosis with mitral regurgitation and aortic regurgitation. Each study group was divided into subgroup with sinus rhythm or atrial fibrillation.

Two-dimensional echocardiography(2DE) and Doppler echocardiography were obtained using phased-array imaging systems with a 3.5/2.0 MHz transducer with Meridian Echocardiography System.

As a standard reference, MVA from 2DE was obtained from end diastolic frame in the standard parasternal short-axis view. The smallest orifice of the mitral valve was carefully identified by scaning from the left atrium to the left ventricle. Optimal frame in the end-diastole was visualized and planimetered to estimate the mitral valve area.

The Doppler derived mitral valve area was calculated using the pressure half-time method. Diastolic transmitral inflow was identified and distinguished from aortic regurgitation using pulsed Doppler mapping technique. Continuous-wave Doppler was used to identify the maximal diastolic velocity across the mitral valve from the apical window. A velocity at half-pressure was estimated by V/1.4,

where V is the maximal velocity, and V/1.4 represents the velocity at which the diastolic transvalvular gradient has fallen by one-half. The pressure half-time is the time from peak to half-pressure. Mitral valve area was then determined by dividing 220 by the pressure half-time. In patients with atrial fibrillation. more than 3 signals were averaged from cardiac cycles with a sufficiently long RR interval to readily identify transmitral velocity. An average gradient was derived from consecutive beats. Beats that were not optimal, due to change in transducer position or other technical factors, were not included in the averaging.

Mean pressure gradient, peak pressure gradient and peak velocity were also obtained from transmitral inflow. A Doppler study was considered positive for valve regurgitation if both an audio and spectral signal were clearly present, and if the spectral signal displayed turbulent flow and the spectral signal was present for the duration of more than 50% of either systole or diastole for a given valve. The severity of valve regurgitation was graded on scale from 0 to 4+(0=none, 1+=mild, 2+= moderate, 3+=moderately severe, and 4+=severe). In case of more than moderate regurgitation. we considered as presence of aortic or mitral regurgitation in this study.

Every measurement from recorded videotapes was obtained from MicroSonics CAD 886 version 2.3 software and HIPAD digitizer which is connected to IBM PC. Linear regression analysis was used to compare each Doppler parameters and standard reference, 2DE-MVA.

RESULTS

The mean value of 2DE-MVA in total 63 patients with sinus rhythm was 1.77 ± 0.52 cm^2 and in total 140 patients with atrial fibrillation was 1.53 ± 0.50 cm^2. The MVA, pressure half-time, mean pressure gradient, peak pressure gradient and peak velocity determined by Doppler echocardiography in sinus

rhythm group were 1.48± 0.44 cm², 164.30± 54.04 msec, 7.39± 3.61 mmHg, 14.87± 5.90 mmHg and 1.89± 0.35 m/sec respectively. As compared with standard reference 2DE-MVA, these Doppler derived MVA, PHT, mean pressure gradient. peak pressure gradient and peak velocity were significantly correlated both in sinus rhythm group with correlation coefficients r=0.903, 0.859, 0.552, 0.479 and 0.498 respectively(P<0.005) and in atrial fibrilla-

tion group with correlation coefficients r=0.896, 0.816, 0.488, 0.451, 0.451 respectively(P<0.005, Talbe 1). Fig. 1 shows correlation between 2DE-MVA and PHT in total 63 patients with sinus rhythm(r=0.859, y= −89x+322, P<0.005) and Fig. 2 shows correlation between 2DE-MVA and PHT in total 140 patients with atrial fibrillation (r=0. 816, y= −115x+374, P<0.005).

In group 1(MS only, n=90), the mean value

Table 1. Correlation between 2DE-MV area and Doppler echocardiographic indices in total patients

|	Sinus rhythm(n=63)			Atrial fibrillation(n=140)		
	Mean± S.D	r value	P value	Mean± S.D	r value	P value
2DE-MVA(cm²)	1.77± 0.52			1.53± 0.50		
Doppler indices						
MVA(cm²)	1.48± 0.44	0.903	0.005	1.25± 0.42	0.896	0.005
Pressure half time(msec)	164.30± 54.04	0.859	0.005	197.82± 70.53	0.816	0.005
Mean pressure gradient(mmHg)	7.39± 3.61	0.552	0.005	7.80± 3.66	0.488	0.005
Peak pressure gradient(mmHg)	14.87± 5.90	0.479	0.005	14.72± 5.37	0.451	0.005
Peak velocity(m/sec)	1.89± 0.36	0.498	0.005	1.89± 0.35	0.451	0.005
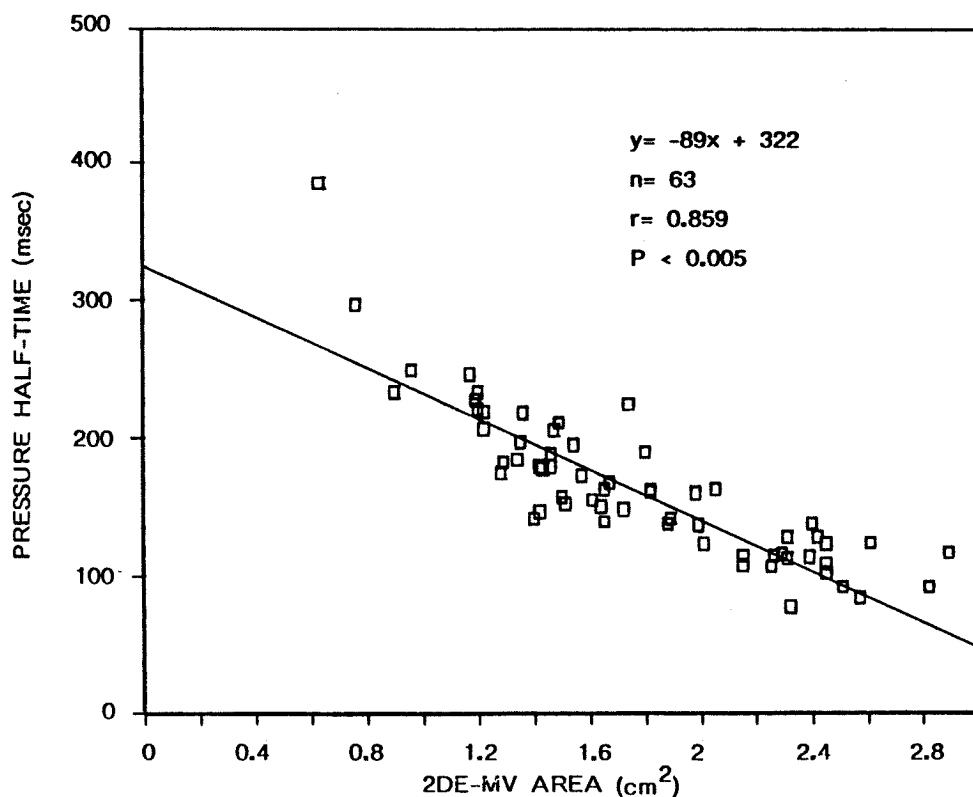
Fig. 1. Correlation between two-dimensional echocardiographic mitral valve area(2DE-MVA) and pressure half-time in total patients with sinus rhythm.

of 2DE-MVA in 32 patients with sinus rhythm was 1.63± 0.50 cm^2 and in 58 patients with atrial fibrillation was 1.45± 0.51 cm^2. The MVA, pressure half-time, mean pressure gradient, peak pressure gradient and peak velocity determined by Doppler echocardiography in sinus rhythm group were 1.37 ± 0.41 cm^2, 178.13± 60.81 msec, 7.86± 3.47 mmHg, 15.57± 5.74 mmHg and 1.94± 0.35 m/sec respectively and these indices in atrial fibrillation group were 1.18± 0.46 cm^2, 216± 81.71 msec, 8.28 ± 4.01 mmHg, 15.0± 45.80 mmHg. 1.90± 0.3 m/sec respectively. As compared with standard reference 2DE-MVA, these Doppler derived MVA, PHT, mean pressure gradient, peak pressure gradient and peak velocity were significantly correlated both in sinus rhythm group with correlation coefficients r=0.907, 0.858, 0.562, 0.445 and 0.457 respectively(<0.005) and in atrial fibrillation group with correlation coefficients r=0.930, 0.842, 0.544, 0.534 and 0.543 respectively(P<0.005, Table 2). Fig. 3 shows correlation between 2DE-MVA and PHT in 32 patients with sinus rhythm(r=0.845, y= −105x+350, P<0.005) and Fig. 4 shows correlation between 2DE-MVA and PHT in 58 patients with atrial fibrillation(r=0.842, y= −136x+413, P<0.005).

In group 2(MS+MR, n=45), the mean value of 2DE-MVA in 13 patients with sinus rhythm was 2.03± 0.59 cm^2 and in 32 patients with atrial fibrillation was 1.59± 0.46 cm^2. The MVA, PHT, mean pressure gradient, peak pressure gradient and peak

velocity determined by Doppler echocardiography in sinus rhythm group were 1.73± 0.53 cm^2, 137.77 ± 44.60 msec, 7.05± 4.80 mmHg, 14.97± 7.33 mmHg and 1.89± 0.44 m/sec respectively and these indices in atrial fibrillation group were 1.33± 0.39 cm^2, 179.00± 58.78 msec, 7.36± 3.71 mmHg, 14.71± 15.60 mmHg and 1.89± 0.36 m/sec respectively. As compared with standard reference 2DE-MVA, these Doppler derived MVA, PHT, mean pressure gradient, peak pressure gradient and peak velocity were significantly correlated both in sinus rhythm group with correlation coefficients r=0. 868, 0.872, 0.731, 0.762 and 0.812 respectivley(P< 0.005) and in atrial fibrillation group with correlation coefficients r=0.830, 0.756, 0.663, 0.664 and 0.628 respectively(P<0.005, Table 3). Fig. 5 shows correlation between 2DE-MVA and PHT in 13 patients with sinus rhythm(r=0.872, y= −66x+272, P<0.005) and Fig. 6 shows correlation between 2DE-MVA and PHT in 32 patients with atrial fibrillation(r=0.756, y= −96x+332, P<0.005).

In group 3(MS+AR, n=54), the mean value of 2DE-MVA in 15 patients with sinus rhythm was 1.78± 0.48 cm^2 and in 39 patients with atrial fibrillation was 1.53± 0.53 cm^2. The MVA, PHT, mean pressure gradient, peak pressure gradient and peak velocity determined by Doppler echocardiography in sinus rhythm group wer 1.45± 0.37 cm^2, 162.87 ± 41.56 msec, 6.58± 2.76 mmHg, 13.14± 5.01 mmHg and 1.78± 0.33 m/sec respectively and these indices in atrial fibrillation group were 1.26±

Table 2. Correlation between 2DE-MV area and Doppler echocardiographic indices in group I(mitral stenosis only)

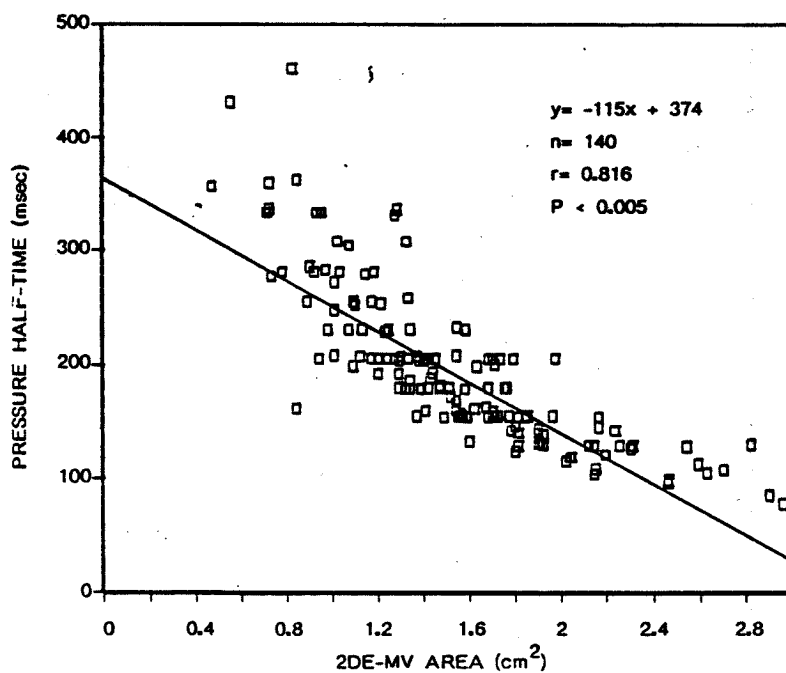|	Sinus rhythm(n=32)			Atrial fibrillation(n=58)		
	Mean± S.D	r value	P value	Mean± S.D	r value	P value
2DE-MVA(cm^2)	1.63± 0.50			1.45± 0.51		
Doppler indices						
MVA(cm^2)	1.37± 0.41	0.907	0.005	1.18± 0.46	0.930	0.005
Pressure half time(msec)	178.13± 60.81	0.858	0.005	216.64± 81.71	0.842	0.005
Mean pressure gradient(mmHg)	7.86± 3.47	0.562	0.005	8.28± 4.01	0.544	0.005
Peak pressure gradient(mmHg)	15.57± 5.74	0.445	0.025	15.04± 5.80	0.534	0.005
Peak velocity(m/sec)	1.94± 0.35	0.457	0.01	1.90± 0.37	0.543	0.005

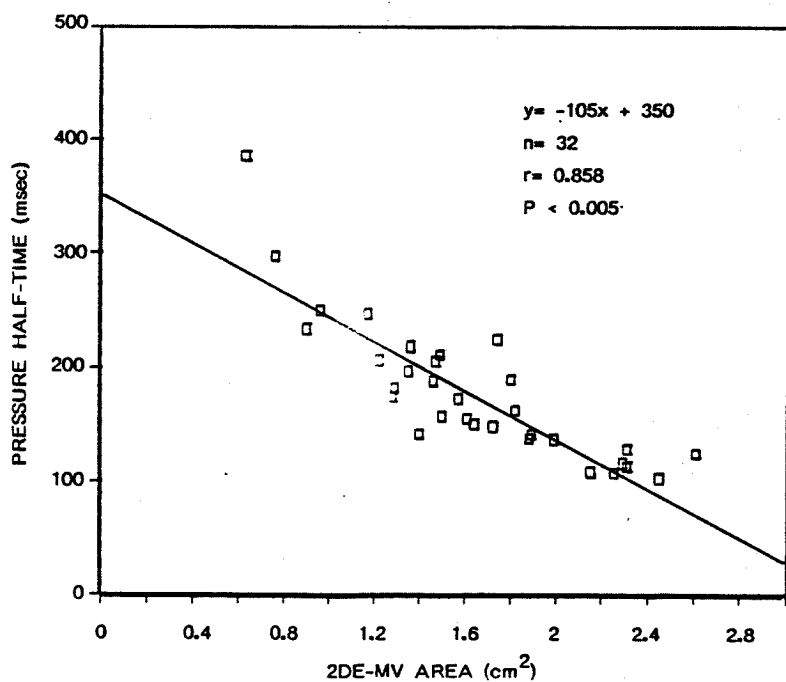Fig. 2. Correlation between 2DE-MVA and pressure half-time in total patients with atrial fibrillation.

Fig. 3. Correlation between 2DE-MVA and pressure half-time in group I(MS only) with sinus rhythm.
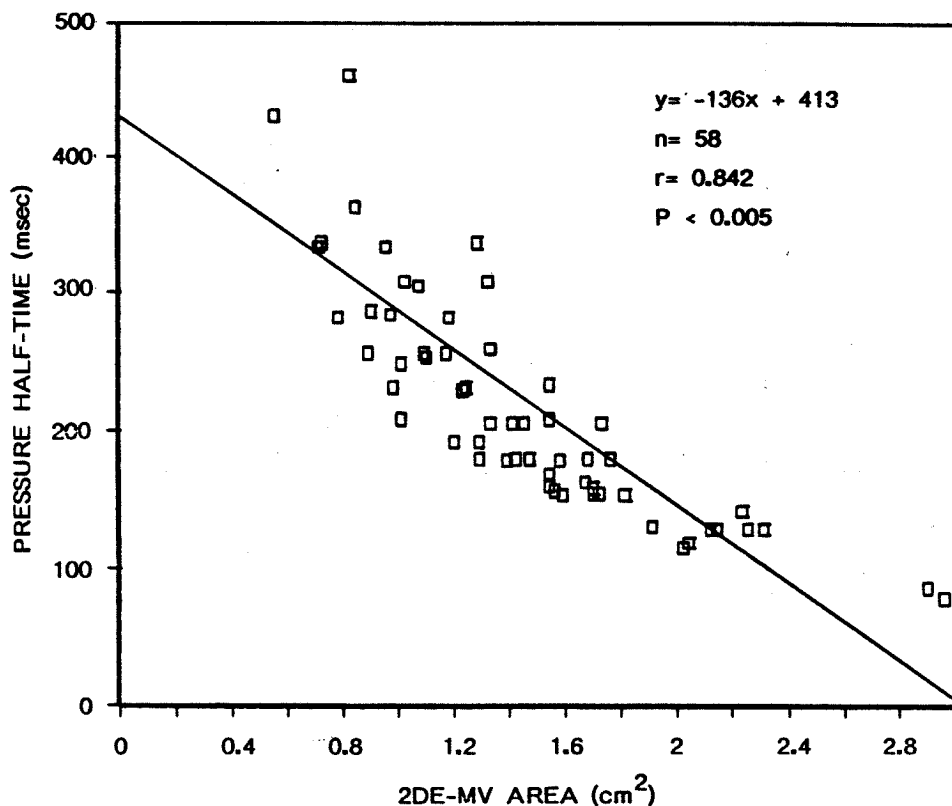
Fig. 4. Correlation between 2DE-MVA and pressure half-time in group I(MS only) with atrial fibrillation.

Table 3. Correlation between 2DE-MV area and Doppler echocardiographic indices in group II(mitral stenosis + mitral regurgitation)

	Sinus rhythm(n=13)			Atrial fibrillation(n=32)		
	Mean ± S.D	r value	P value	Mean ± S.D	r value	P value
2DE-MVA(cm²)	2.03± 0.59			1.59± 0.46		
Doppler indices						
MVA(cm²)	1.73± 0.53	0.868	0.005	1.33± 0.39	0.830	0.005
Pressure half time(msec)	137.77± 44.60	0.872	0.005	179 ± 58.78	0.756	0.005
Mean pressure gradient(mmHg)	7.05± 4.80	0.731	0.005	7.36± 3.71	0.663	0.005
Peak pressure gradient(mmHg)	14.97± 7.33	0.762	0.005	14.71± 15.60	0.644	0.005
Peak velocity(m/sec)	1.89± 0.44	0.812	0.005	1.89± 0.36	0.628	0.005

0.39 cm², 192.46± 62.15 msec, 7.98± 3.26 mmHg, 14.85± 4.92 mmHg and 1.90± 0.31 m/sec respectively. As compared with standard reference 2DE-MVA, these Doppler derived MVA, PHT were significantly correlated both in sinus rhythm group with correlation coefficients r=0.934, 0.900(P<0.005) and in atrial fibrillation group with correlation coefficients r=0.897, 0.838(P<0.005). But the mean pressure gradient, peak pressure gradient and peak velocity were not correlated with 2 DE-MVA in both subgroups(Talbe 4). Fig. 7 shows correlation between 2DE-MVA and PHT in 15 patients with sinus rhythm(r=0.900, y= −77x+301, P<0.005) and Fig. 6 shows correlation betwwen 2DE-MVA and PHT in 39 patients with atrial fibrillation(r=0.838, y= −99x+344, P<0.005).
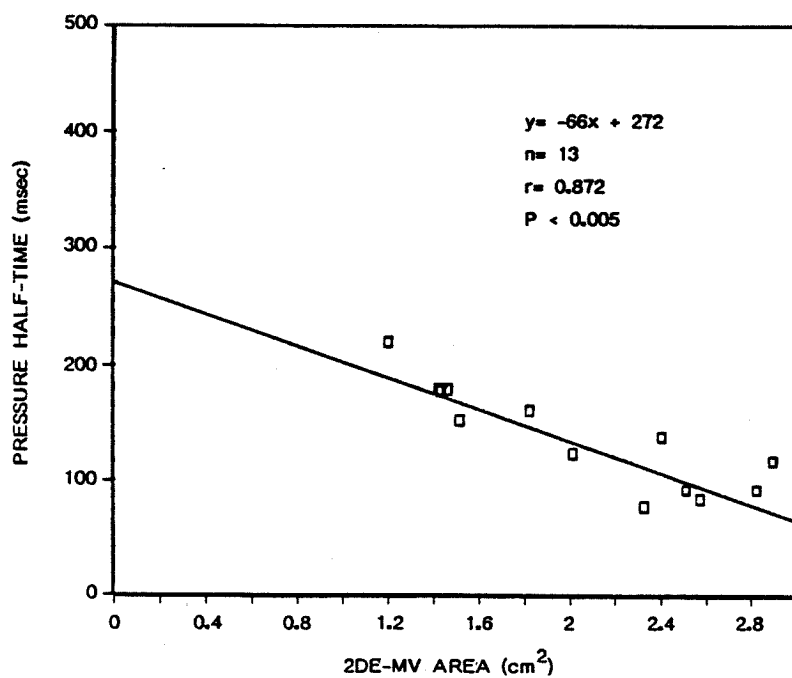
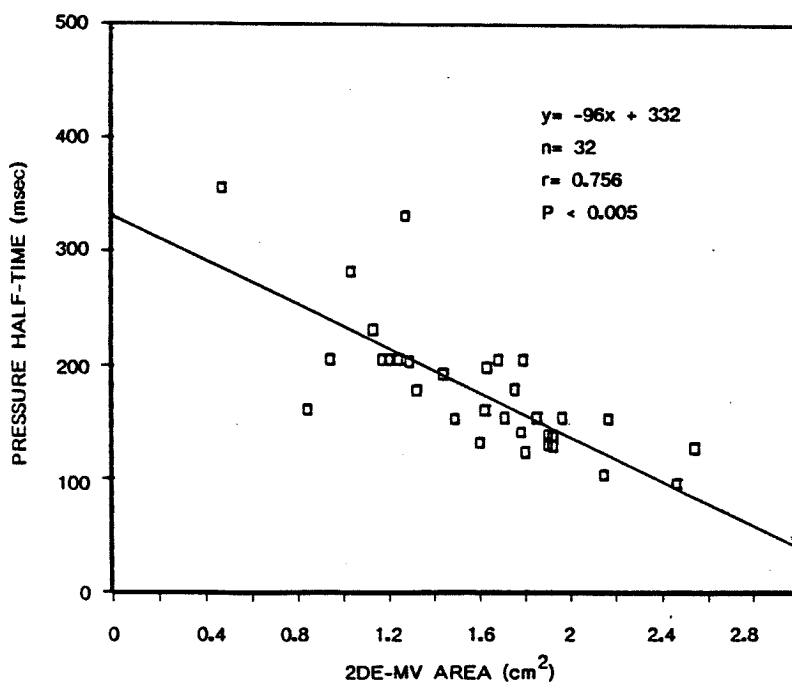Fig. 5. Correlation between 2DE-MVA and pressure half-time in group II(MS+MR) with sinus rhythm.

Fig. 6. Correlation between 2DE-MVA and pressure half-time in group II(MS+MR) with atrial fibrillation.

Table 4. Correlation between 2DE-MV area and Doppler echocardiographic indices in group III(mitral stenosis + aortic regurgitation)

	Sinus rhythm(n=15)			Atrial fibrillation(n=39)		
	Mean± S.D	r value	P value	Mean± S.D	r value	P value
2DE-MVA(cm^2)	1.78± 0.48			1.53± 0.53		
Doppler indices						
MVA(cm^2)	1.45± 0.37	0.934	0.005	1.26± 0.39	0.897	0.005
Pressure half time(msec)	162.87± 41.56	0.900	0.005	192.46± 62.15	0.838	0.005
Mean pressure gradient(mmHg)	6.58± 2.76	0.233	N.S	7.98± 3.26	0.243	N.S
Peak pressure gradient(mmHg)	13.14± 5.01	0.198	N.S	14.85± 4.92	0.201	N.S
Peak velocity(m/sec)	1.78± 0.33	0.207	N.S	1.90± 0.31	0.209	N.S

N.S : Not significant

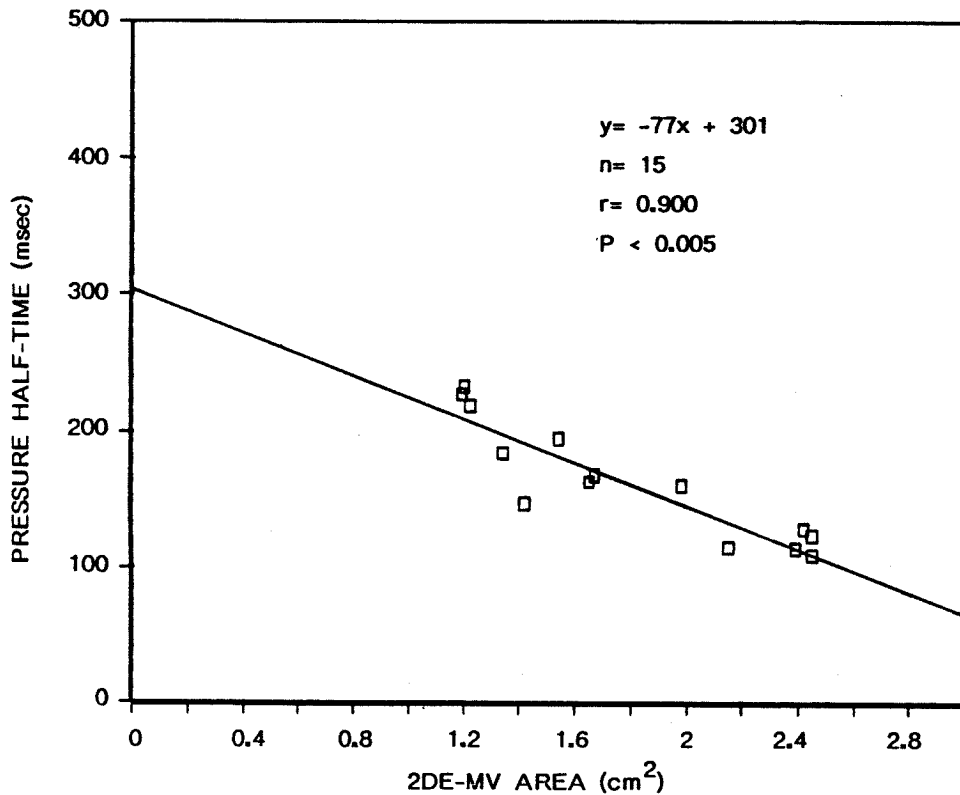$y = -77x + 301$
$n = 15$
$r = 0.900$
$P < 0.005$

Fig. 7. Correlation between 2DE-MVA and pressure half-time in group III(MS+AR) with sinus rhythm.

In group 4(MS+MR+AR, n=14), the mean value of 2DE-MVA in 3 patients with sinus rhythm was 1.99± 0.31 cm^2 and in 11 patients with atrial fibrillation was 1.77± 0.40 cm^2. The MVA, PHT, mean pressure gradient, peak pressure gradient and peak velocity determined by Doppler echocardiography in sinus rhythm group were 1.63± 0.25 cm^2, 139.00± 24.00 msec, 7.84± 4.19 mmHg, 15. 67± 5.98 mmHg and 1.96± 0.37 m/sec respectively and these indices in atrial fibrillation group were 1.35± 0.31 cm^2, 172.40± 41.00 msec, 5.94± 2.36 mmHg, 12.58± 3.72 mmHg and 1.76± 0.26 m/sec respectively. As compared with standard reference 2DE-MVA, these Doppler derived indices were not
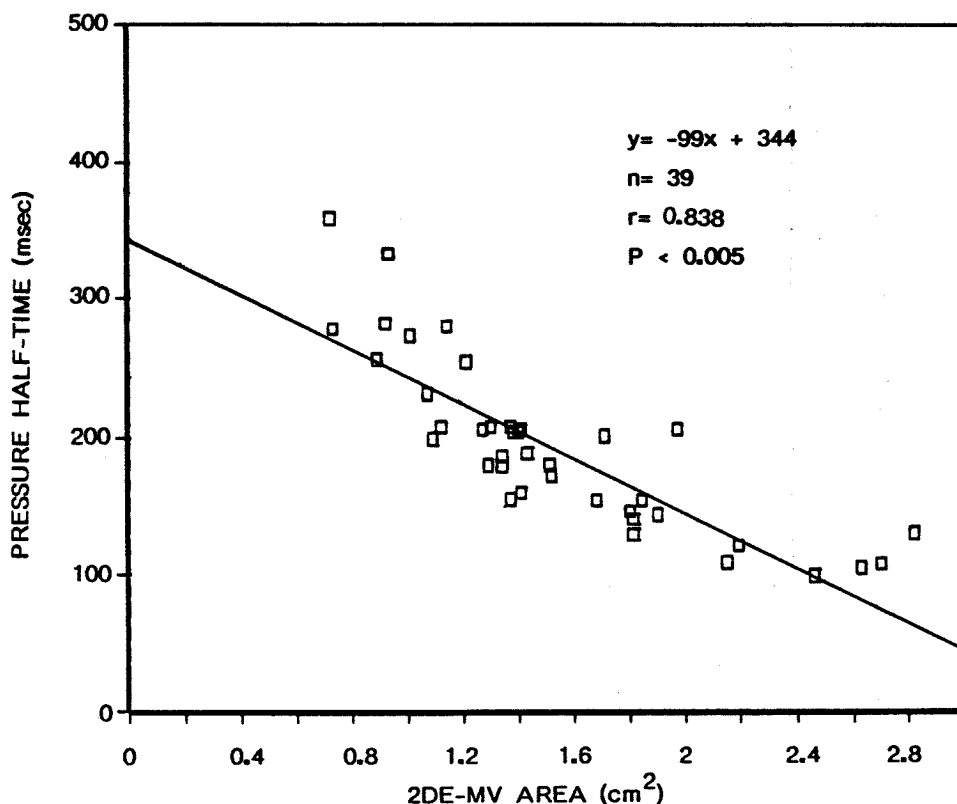
Fig. 8. Correlation between 2DE-MVA and pressure half-time in group III(MS+AR) with atrial fibrillation.

Table 5. Correlation between 2DE-MV area and Doppler echocardiographic indices in group IV(MS+ MR+AR)

	Sinus rhythm(n=3)			Atrial fibrillation(n=11)		
	Mean± S.D	r value	P value	Mean± S.D	r value	P value
2DE-MVA(cm²)	1.99± 0.31			1.77± 0.40		
Doppler indices						
MVA(cm²)	1.63± 0.25	0.445	NS	1.35± 0.31	0.889	P<0.005
Pressure half time(msec)	139 ± 24	0.339	NS	172.4±41.0	0.789	P<0.005
Mean pressure gradient(mmHg)	7.84± 4.19	0.908	NS	5.94± 2.36	0.173	N.S
Peak pressure gradient(mmHg)	15.67± 5.98	0.915	NS	12.58± 3.72	0.011	N.S
Peak velocity(m/sec)	1.96± 0.37	0.828	NS	1.76± 0.26	0.020	N.S

N.S : Not significant

correlated significantly in sinus rhythm group. But Doppler derived MVA and PHT in atrial fibrillation group were correlated significantly with 2DE-MVA (P<0.05, Table 5). Fig. 9 shows correlation between 2DE-MVA and PHT in 3 patients with sinus rhythm(r=0.339, y= −26x+191) and Fig. 10 shows correlation 2DE-MVA and PHT in 11 patie-

nts with atrial fibrillation(r=0.789, y= −80x+ 313.9, P<0.005).

DISCUSSION

Our findings in patients with mitral stenosis suggests that the determination of mitral valve area
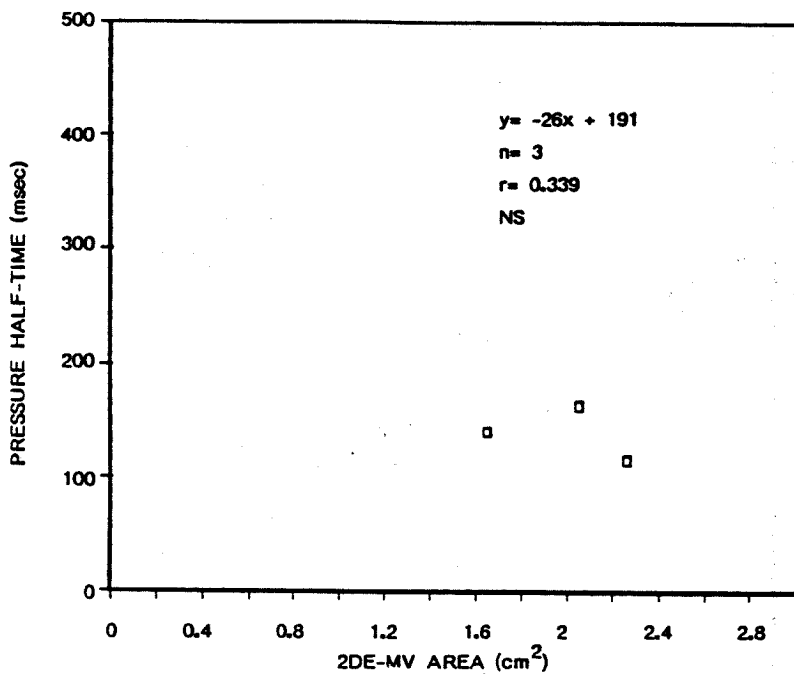
Fig. 9. Correlation between 2DE-MVA and pressure half-time in group IV(MS+MR+AR) with sinus rhythm.
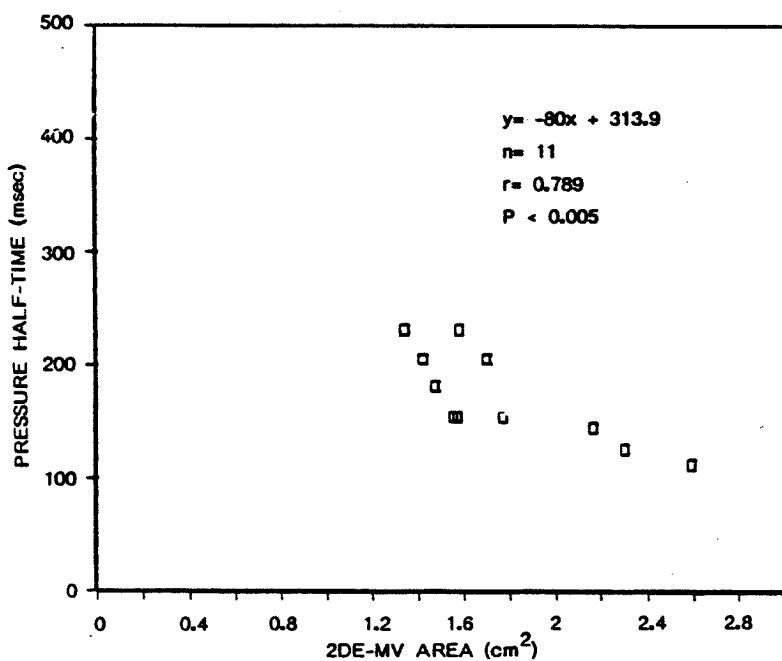

Fig. 10. Correlation between 2DE-MVA and pressure half-time in group IV(MS+MR+AR) with atrial fibrillation.

by the pressure half-time is significantly correlated with two-dimensional mitral valve area even in the presence of atrial fibrillation.

Previous studies comparing MVA by two-dimensional echocardiography with those by the Gorlin equation with values derived from cardiac catheterization have reported good correlation[11-15]. Accordingly, echocardiography is currently the most widely used method for the noninvasive estimation of MVA. The 2DE-MVA used as standard reference in this study. However, this method is dependent on technically optimal studies, proper gain settings and locating the true orifice in the short-axis view [12].

Hatle et al[1,16] used continuous wave Doppler recordings of transmitral flow velocity to determine PHT noninvasively. In general, the best type of Doppler to use in mitral stenosis is continuous wave, since it is able to record higher velocities than pulsed wave Doppler. After gain of the best spectrum of the diastolic flow through the mitral valve, there are four main parameters to be analyzed.

Primarily, peak velocity is considerably higher than normal. The more severe the mitral stenosis, the higher the peak velocity, but since the peak velocity represents flow across the valve, it depend on heart rate and cardiac output. Therefore in case of atrial fibrillation, beat to beat variation of peak velocity may be cause of inaccurate measurement of MVA from PHT method.

The second parameter is the diastolic slope of the velocity profile. This slope is decreased in mitral stenosis, becoming increasingly more flat as the mitral stenosis becomes more severe. This variation of diastolic slope may be cause of error in calculation of MVA. But by the report of Hatle et al, Doppler spectral signals show minimal variation in the rate of decline from peak velocity, despite irregular rhythms[1]. Maximal early diastolic opening may be difficult to discern by two-dimensional echocardiography in patients who have very irregular rhythms[12].

The third parameter is pressure half-time. The initial concept of assessing the severity of mitral stenosis by the time required for the early diastolic transmitral gradient to decreased to one-half its maximal value was introduced in 1966 by Libanoff and Rodbard[17]. Values of 60 msec or less are considered normal, with values of more than 100 msec being found in mitral stenosis. Since pressure half-time is not influenced by heart rate and cardiac output, it gives a better evaluation of the degree of stenosis.

The fourth parameter, the mitral valve orifice area can be determined by dividing an empirically derived constant of 220 by the Doppler PHT[1,18].

Bryg et al reported excellent correlation between MVA estimates from Doppler PHT, catheterization and echocardiographic planimetry in patients with atrial fibrillation and mitral regurgitation. The correlation coefficient between Doppler and two-dimensional echocardiography was 0.88 in patients with pure mitral stenosis in sinus rhythm, 0.93 in patients with mitral regurgitation and 0.96 in patients with atrial fibrillation[19]. These correlations could be reproduced in our study, there was good correlation in patients with mitral regurgitation($r=$ 0.868) and in patients with atrial fibrillation($r=0.$ 930).

In addition to the above results, PHT and MVA from Doppler method in mitral stenosis patients with mitral regurgitation and atrial fibrillation correlated well with 2DE-MVA($r=0.756, 0.830, P<0.$ 005). And in patients with aortic regurgitation and atrial fibrillation. PHT and MVA from Doppler method also correlated well with 2DE-MVA(($r=0.$ 838, 0.897, $P<0.005$). Furthermore, even in patients of mitral stenosis combined with mitral and aortic regurgitation who had atrial fibrillation, PHT and MVA from Doppler method showed good correlation with 2DE-MVA($r=0.789, 0.889, P<0.$ 005). Therefore Doppler echocardiography could estimate valve area in patients with mitral stenosis

regardless of presence of mitral and aortic and atrial fibrillation.

In comparison with MVA calculation by cardiac catheterization, Doppler PHT method reproduces MVA more accurately especially in cases of atrial fibrillation. Calculation of mitral valve orifice area in mitral stenosis using hemodynamic data obtained at cardiac catheterization[20] is limited by need to perform an invasive procedure and by the increased difficulty in calculating effective mitral orifice area size in the presence of atrial fibrillation, mitral regurgitation or a low cardiac output state[21-24].

In conclusion, the estimation of MVA in patients with mitral stenosis by Doppler echocardiography using pressure half-time can be used for those patients associated with mitral and/or aortic regurgitation regardless of the presence of atrial fibrillation.

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