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Practical Value of Echo Doppler Evaluation of Aortic and Mitral Stenosis: A Comparative Study with Cardiac Catheterization

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This retrospective analysis compares data derived by echocardiography and cardiac catheterization in the evaluation of aortic and mitral valve stenosis. Sixty-seven patients, aged 69 ± 12 years, underwent 76 catheterization procedures. In all studies the Doppler recording was technically adequate. In 64 studies of patients with aortic stenosis, correlation was good between the gradient obtained at catheterization (peak 51 ± 28 mm Hg, mean 48 ± 24 mm Hg) and the Doppler gradient (peak 73 ± 29 mm Hg, mean 41 ± 17 mm Hg) (R = 0.78 peak, 0.77 mean). In 15 studies the aortic valve area, 0.8 ± 0.2 cm², calculated by the simplified continuity equation, correlated well with the catheterization valve area, 0.7 ± 0.3 cm², calculated by the Gorlin equation (R = 0.80). In 14 studies in mitral stenosis patients, the mean gradient at catheterization was 11 ± 5 mm Hg compared to the Doppler gradient of 8 ± 4 mm Hg (R = 0.58). The mitral valve area was 1.1 ± 0.3 cm² by the Gorlin equation and 1.2 ± 0.3 cm² by echo Doppler, using pressure half-time. When cardiac rhythm, the presence and severity of regurgitation, and the cardiac index were analyzed, none was shown to have demonstrable influence on the accuracy of the Doppler study. Doppler echocardiography can be used reliably to assess valvular stenosis in a clinical, noninvasive laboratory where routine tests are performed and interpreted by more than one individual. (Henry Ford Hosp Med J 1990;38:87-90)

The assessment of the severity of valvular heart disease on the basis of symptoms and clinical findings alone is sometimes difficult. Noninvasive studies using M-mode and two-dimensional echocardiography are helpful in assessing the functional significance of heart murmurs but have variable reliability (1,2). In 1980, Hatle et al (3) reported that estimation of transaortic and mitral pressure gradient is possible by Doppler ultrasound using a simplified Bernoulli equation. Yeager et al (4) reported good correlation between pressure gradients determined by Doppler ultrasound and those obtained by cardiac catheterization. Echocardiographic mitral valve area derived from Doppler pressure half-time has been employed routinely to quantify the degree of stenosis (5). Recently, aortic valve area has been calculated directly by Doppler echocardiography through the use of a simplified continuity equation which is considered to be uninfluenced by the presence of aortic regurgitation (6,7).

In this study of methods to evaluate the severity of valve stenosis, we compared data derived by echocardiography with those obtained by cardiac catheterization. The purpose was to assess the accuracy of Doppler echo studies (in determining the degree of stenosis) when performed in a laboratory setting involving many technicians and physicians.

Study Group

In 15 months, 67 patients underwent cardiac catheterization for clinically suspected aortic and/or mitral valve disease. All patients also had a technically adequate Doppler study. Sixty-seven patients underwent 76 catheterization procedures. Seven patients had repeat study following balloon dilatation of the aortic valve (six patients) or mitral valve (one patient). Catheterization was repeated in two additional patients because of suspected clinical progression of the stenosis. Thus, there were 62 aortic, 12 mitral, and two combined valvular disease studies.

The study group consisted of 40 males and 27 females with a mean age of 69 ± 12 years. The Doppler study was carried out 12 ± 20 days prior to the catheterization, except for two cases where it antedated the catheterization by six months.

Methods

All Doppler studies were performed by four technicians, using a Hewlett-Packard ultrasound imaging system and 2.5 MHz transducer. They were read by four echocardiographers who were unaware of the catheterization data. Five views were attempted in all Doppler studies (left parasternal, right parasternal, suprasternal, apical, and subcostal), and the optimal, maximal velocity signal was used to determine the gradient. Angle of incidence correction was not utilized. The peak maximal instan-

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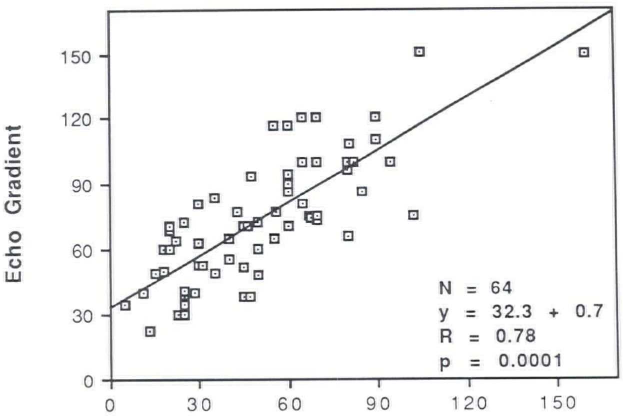

Fig 1—Correlation between aortic Echo Doppler maximal instantaneous gradient and catheterization peak-to-peak gradient.

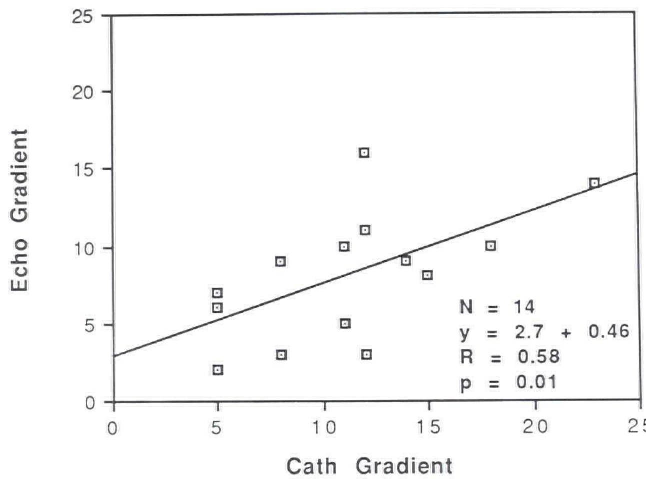

Fig 2—Correlation between mitral Echo Doppler mean gradient and catheterization mean gradient.

taneous pressure gradient was calculated by means of a simplified Bernoulli equation and compared to the peak-to-peak pressure gradient across the aortic valve obtained during cardiac catheterization. In addition, the mean pressure gradient by Doppler ultrasound was calculated by means of Hewlett-Packard digitized computer from the area under the velocity curve. This value was compared with the mean pressure gradient measured by the standard method during cardiac catheterization.

Five consecutive cycles were averaged for patients with sinus rhythm (63 cases) and ten cycles for patients with atrial fibrillation (13 cases). Doppler-derived mitral valve area using pressure half-time was compared with catheterization-determined valve area using the Gorlin formula. In 15 patients with aortic stenosis, the valve area using the Doppler simplified continuity equation was available and was compared with the corresponding area calculated by the Gorlin formula (8,9). Aortic regurgitation and mitral regurgitation were determined by aortography

Table 1
Correlation Between Echo Doppler Findings and Catheterization Measurements in Both Aortic and Mitral Stenosis Groups

	N	Doppler	Cath	R	P-Value
Aortic Stenosis:					
Peak gradient (mm Hg)	64	73 ± 29	51 ± 28	0.78	0.0001
Mean gradient (mm Hg)	64	41 ± 17	48 ± 24	0.77	0.0002
Aortic valve area (cm^2) (using continuity equation)	15	0.85 ± 0.2	0.7 ± 0.3	0.80	0.003
Mitral Stenosis:					
Mean gradient (mm Hg)	14	8 ± 4	11 ± 5	0.58	0.01
Mitral valve area (cm^2)	14	1.2 ± 0.3	1.1 ± 0.3	0.58	0.02

and left ventriculography or by Doppler echocardiography. This was graded in severity from 0 to 4+ (1+ mild, 2+ moderate, 3+ moderately severe, and 4+ severe) (10,11). The cardiac output was calculated by the standard thermodilution method. The catheterization, angiographic, and hemodynamic data were analyzed without knowledge of echocardiographic data.

Statistical Analysis

The data were analyzed using simple regression analysis to determine the correlation coefficient R for all study groups, and the Student *t* test was used to calculate a P value. The following were compared:

1. Peak instantaneous pressure gradient by the Doppler technique and peak-to-peak gradient by catheterization for aortic stenosis.
2. Mean pressure gradient by Doppler ultrasound and cardiac catheterization for both aortic and mitral stenosis.
3. Mitral valve area by Doppler using the pressure half-time and by catheterization using the Gorlin formula.
4. The subgroup with Doppler-derived aortic valve area by the continuity equation and the corresponding catheterization valve area by the Gorlin formula.
5. Influences of rhythm, presence and severity of regurgitation, and the cardiac index on invasive versus noninvasive measurements were also analyzed.

All values are expressed in mean ± standard deviation. A P-value of less than 0.05 is considered statistically significant.

Results

Aortic stenosis

The mean maximal instantaneous pressure gradient by Doppler of 73 ± 29 mm Hg compared well with the catheterization peak gradient of 51 ± 28 mm Hg (R = 0.78) (Fig 1). Similar comparability was also found for the mean gradients (R = 0.77) (Table 1).

In 15 cases in which continuity-equation Doppler valve area was available, correlation with catheterization valve area was very good (R = 0.80).

The effects of cardiac rhythm, presence of moderate or severe regurgitation, and low cardiac index are shown in Table 2. In patients with aortic stenosis, none of these factors influenced the

Table 2
Effect of Cardiac Rhythm, Regurgitation, and Cardiac Index on the Correlation of Aortic Valve Peak and Mean and Mitral Valve Mean Gradients

		Peak Gradient (mm Hg)			Mean Gradient (mm Hg)		
	N	Doppler	Cath	R	Doppler	Cath	R
Aortic Stenosis:							
Sinus rhythm	58	51 ± 30	74 ± 30	0.78	41 ± 18	48 ± 25	0.77
Atrial fibrillation	6	68 ± 11	52 ± 12	0.75	40 ± 6	48 ± 17	0.69
≤ 2+ AR	33	76 ± 31	57 ± 33	0.82	43 ± 19	52 ± 26	0.79
≥ 3+ AR	4	89 ± 18	59 ± 2	0.77	46 ± 10	60 ± 9	0.85
Cardiac index < 2.5	37	70 ± 29	46 ± 26	0.81	40 ± 19	45 ± 24	0.78
Cardiac index ≥ 2.5	27	78 ± 28	58 ± 30	0.77	42 ± 15	54 ± 24	0.78
Mitral Stenosis:							
Sinus rhythm	6				10 ± 4	11 ± 3	0.22
Atrial fibrillation	8				7 ± 4	12 ± 6	0.84
≤ 2+ MR	11				8 ± 4	11 ± 4	0.60
≥ 3+ MR	3				11 ± 3	13 ± 7	0.97
Cardiac index < 2.5	7				9 ± 4	12 ± 6	0.58
Cardiac index ≥ 2.5	7				7 ± 3	11 ± 4	0.57

Note: AR = aortic regurgitation, and MR = mitral regurgitation.

good correlation between catheterization and Doppler gradients.

Mitral stenosis

The mean value of the mean pressure gradients across the mitral valve was 8 ± 4 mm Hg by Doppler and 11 ± 5 mm Hg by catheterization, resulting in a correlation coefficient of $R = 0.58$ ($P < 0.01$) (Fig 2). The mitral valve area calculated by Doppler pressure half-time correlated well with catheterization valve area calculated by the Gorlin formula ($R = 0.58$; $P = 0.02$).

In patients with mitral stenosis and sinus rhythm, mean gradients were not significantly correlated despite similar average values obtained by the two methods. This is attributed to the small number of patients. Moreover, in one of these patients there was an unexplained large difference in the two observed gradients.

The presence of moderate or severe mitral regurgitation or low cardiac index did not influence the good correlation between catheterization and Doppler mean gradients.

Discussion

Over the last three decades cardiac catheterization has been the diagnostic procedure of choice for determining the severity of valvular stenosis. Recent studies, however, have demonstrated that aortic and mitral pressure gradients can be determined reliably by Doppler echocardiography (1-7). These studies have generally been performed and scrutinized rigorously as part of a research protocol. In our study we tested the validity of Doppler echo evaluations of valvular areas in the routine, noninvasive laboratory where four technicians and four physicians were involved.

In the evaluation of aortic stenosis we found good correlation between the catheterization mean and peak-to-peak gradient and the Doppler mean and maximal instantaneous gradient, respectively. Accurate measurement of the maximal instantaneous pressure gradient is not obtained routinely during cardiac catheterization whereas peak-to-peak and mean gradients are recorded routinely. The latter are usually slightly lower than the maximal instantaneous pressure gradient. However, peak pressure gradients by the two methods are closely correlated. Correlation was not influenced by atrial fibrillation, aortic or mitral regurgitation, or cardiac index of less than 2.5 L/min.

In mitral stenosis, the mean gradient by Doppler echo correlated reasonably well with the catheterization mean gradient. Correlation was good even when significant mitral regurgitation was present. Mitral valve area calculated by Doppler pressure half-time correlated well with catheterization-calculated valve area using the Gorlin formula. The accuracy and validity of valve area estimation by pressure half-time has been questioned recently (12-16) but our data confirm its value.

In 15 patients where echocardiographic aortic valve area was calculated using the Doppler simplified continuity equation, there was excellent correlation with the aortic valve area calculated by the Gorlin formula in the catheterization laboratory ($R = 0.71$). Furthermore, when the Gorlin-derived valve area was corrected for the degree of aortic regurgitation, the correlation improved ($R = 0.80$). Doppler-derived aortic valve areas were within 0.3 cm^2 of the corresponding catheterization valve area in all but two cases. Thus, when technically feasible, Doppler-derived aortic valve area by the continuity equation is very reliable. Unlike catheterization-derived valve area, where correction for aortic regurgitation needs to be incorporated, the Doppler continuity equation aortic valve area calculation is not influenced by the presence of aortic regurgitation.

Our data permit the following conclusions:

1. Doppler echocardiography is a practical, reliable, noninvasive method that can guide the clinician in estimating the severity of aortic and/or mitral stenosis. The procedure is valuable not only in the research laboratory but also in the routine office setting.

2. Doppler echocardiography allows accurate estimation of the pressure gradients across the aortic and mitral valves.

3. Mitral valve area estimation using Doppler pressure half-time correlates well with the catheterization valve area.

4. Doppler continuity equation aortic valve area is very reliable and is not influenced by the presence of aortic regurgitation.

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