Evaluation of the Severity of Aortic Valve Stenosis by Ejection Fraction-Velocity Ratio: Function–Corrected Index in Children

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Abstract

Background- In the evaluation of the severity of aortic valve stenosis with echocardiography or catheterization, ventricular function seems to have an impact on the estimation of preferential non-invasive procedure of echocardiography.

Methods-Fifty-seven patients**,** who had valvar aortic stenosis without any left heart lesion or ventricular septal defect, were referred to our department for an examination. Mean pressure gradient and indexed aortic valve area (to body surface area) based on the continuity equation, and ejection fraction ratio to peak and mean velocities and pressure gradients across the aortic valve ("function-corrected" indices) were calculated by echocardiography and were compared with one another. The patients were subsequently classified into four groups based on their ejection fraction, and the calculations were done in each group again.

Results- In the two groups of ejection fraction less than 65% and more than 85%, the inadequacy in the number of cases precluded a judgment. In the group of ejection fraction between 65% and 75%, there were good correlations between mean gradients and the ratios and good correlation between indexed aortic valve area and the ratios to velocities, but not pressure gradients. In the group of ejection fraction between 75% and 85%, there were good correlations between all of those variables.

Conclusion- In the intermediate spectra of the ejection fraction and consequently ventricular function, there were no differences between "function-corrected" indices and previous estimations of mean gradients and aortic valve areas. There is, however, need for further studies with larger numbers of patients to evaluate the correlation of the "function–corrected" indices with mean gradients and aortic valve areas in the upper and lower limits of ejection fraction ***(Iranian Heart Journal 2007; 8 (1): 24-29)***.

Key words: aortic valve stenosis ■ ejection fraction ■ pressure gradient ■ valve area■ echocardiography

Two–dimensional and Doppler echocardiography are current and non-invasive methods for defining the anatomy and the hemodynamic severity of aortic valve stenosis.[1]

Doppler peak instantaneous pressure gradient, Doppler mean gradient, and determination of the aortic valve area by the continuity equation have been techniques for the evaluation of the severity of aortic valve stenosis up to now.[2-7]

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Ventricular function has an affect on the pressure gradients. On the other hand, small left ventricular outflow tract and rapid heart beat in small children cause problems in the estimation of size, and the squaring of it leads to larger pitfalls when using the continuity equation. Calculation of aortic valve area by the continuity equation is also time–consuming.[8,9]

The simplified index of Ejection Fraction–Velocity Ratio (EFVR = percent LV ejection fraction/4V^2), which was suggested by Antonini-Canterin and colleagues, is simple and may be a practical method for evaluating the severity of aortic valve stenosis.[10-11]

Methods

Patient population

Our study consisted of patients referring to the pediatric outpatient clinic of our heart center over a one-year period (April 2003 – March 2004). Inclusion criterion was aortic valve stenosis, and exclusion criteria were all of the other left heart lesions and VSD. Trivial to mild MR was the exception. There were 57 pediatric patients: 18 girls and 39 boys at a mean age of 5.73±4.63 years (range: 6 months to 18 years).

All the subjects were in sinus rhythm. All two-dimensional and Doppler echocardiography examinations were performed by a pediatric cardiologist utilizing Vingmed 800 ultrasound imaging equipment with a 5-Hz mechanical transducer. If the child was not cooperative, chloral hydrate (75-100mg/kg) was used orally.

The continuity equation-derived valve area calculation was performed as:

$$AVA = CSA_{AoV} \times PPG_{AoV} / PPG_{AoV}$$

where AVA=aortic valve area, CSA = cross sectional area, AoV = aortic valve, LVOT = left ventricular outflow tract, PPG = peak pressure gradient.

The area of the LVOT was calculated as: $(\text{diameter}/2)^2$ ×ת, by means of digital calipers in the parasternal long-axis view just below the insertion of the anterior and posterior aortic valve leaflets during mid-systole.[12] The LVOT velocity was recorded by pulse Doppler from apical four-chamber view with the transducer tilted anteriorly to visualize the aortic valve and the sample volume moving from the inferior portion of the outflow tract toward the aortic valve until velocities began to increase steeply. The tracing obtained before the steeply increasing velocities was used to calculate the peak velocity of the LVOT.[13]

Maximal velocity of the aortic jet was obtained by using continuous Doppler wave in apical five-chamber, suprasternal or right parasternal views, in which the maximum velocity was recorded. The maximal instantaneous gradient across the aortic valve and the mean gradient were derived from aortic Doppler velocities by the Bernoulli equation $\{[PPG = 4\,(PV_1^2 - PV_2^2)]$, where PPG = peak pressure gradient, PV_1 = peak velocity in place 1, PV_2 = peak velocity in place 2$\}$. If the proximal velocity to aortic jet was equal or less than 1, the simplified Bernoulli equation was used $[PPG = 4\,(PV)^2]$.[1] All the velocities were averaged over 3 to 5 beats. Because of the different sizes of the children, the continuity equation-derived aortic valve areas were indexed according to their body surface area (BSA) as: IAVA = AVA / BSA (where IAVA = indexed aortic valve area).

The EFVRs were calculated as: EFVR = percent LV ejection fraction / Doppler-derived aortic gradient. Estimation of ejection fraction was recorded by M-mode echocardiography sizing.

Some of the patients were then admitted to the catheterization room, but only 7 of them had successful entering of the catheter into the LV. Consequently, as it was not statistically sound to use the data in the calculations, we were not able to use all of the patients' catheterization data.

Statistical analysis

Echo-Doppler data were analyzed by SPSS11 software. The results are expressed as mean value ± standard deviation (mean ± SD).

Results

In 4 patients, the maximum gradients were recorded from suprasternal, and in the remaining ones from apical four-chamber views. We had 39 males and 18 females. Data of their ages, weights (W), heights (H) and body surface areas (BSA) are shown in Table I.

Table I. Mean ± SD of the patients' ages, weights, heights and body surface areas.

	Mean	SD
Age (Y)	5.73	4.64
W (Kg)	21.09	14.89
H (Cm)	108.96	35.44
BSA (M^2)	0.78	0.41

Data on the patients, velocities, gradients, aortic valve areas, and EFVRs are shown in Table II.

Table II. Mean±SD of patients' velocities, gradients and EFVRs.

AoV	Mean	SD
PV_{AoV}(m/s)	3.65	0.94
MV_{AoV}(m/s)	2.47	0.66
PPG_{AoV}(mmHg)	53.84	30.16
MPG_{AoV}(mmHg)	31.32	17.32
AVA(cm^2)	0.55	0.39
IAVA(cm^2/m^2)	0.67	0.25
EF(%)	78	9
EF/PV	0.23	0.06
EF/MV	0.34	0.09
EF/PPG	0.02	0.01
EF/MPG	0.03	0.02

(PV = peak velocity, MV = mean velocity, PPG = peak pressure gradient, MPG = mean pressure gradient, AoV = aortic valve, AVA = aortic valve area, IAVA = Indexed AVA, EF = ejection fraction.

The correlation between IAVA and MPG_{AoV} was obtained, which was inversely over intermediate (P value = 0.01, r = 0.610).

Afterwards, the patients were classified into 3 groups based on IAVA (IAVA $\leq$ 0.5, 0.5 < IAVA $\leq$ 0.8, and 0.8 < IAVA)[1] and MPG (27 $\leq$ MPG, 17 $\leq$ MPG < 27, and MPG < 17)[13] distinctly. The correlation between the 3 subgroups of each classified group was inversely intermediate (P value<0.01, r=0.507).

The correlation of IAVA and MPG_{AoV} with EFVRs (EF / PV_{AoV}, EF / MV_{AoV}, EF / PPG_{AoV}, EF / MPG_{AoV}) was examined. The correlation of IAVA with EFVRs was over intermediate (P-value < 0.001, r > 0.598), and the correlation of MPG_{AoV} with EFVRs was inversely well (P-value < 0.001, r $\leq$ -0.784).

At this stage, the patients were classified into 4 subgroups on the basis of their ejection fractions (EF $\leq$ 65%, 65% < EF $\leq$ 75%, 75% < EF $\leq$ 85%, and EF >85%), as depicted in Table III.

Table III. Number of patients in each subgroup based on their ejection fractions.

EF	Number of patients
≤65%	3
65%< ≤75%	18
75%< ≤85%	30
>85%	6

In each group, the correlation of IAVA and MPG_{AoV} with EFVRs was examined; the data are shown in Tables IV - VII.

Table IV. The correlation of IAVA and MP_{AoV} with $EFVR_S$ in subgroup of EF ≤ 65%.

EF ≤ 65%, N=3	IAVA	MPG_{AoV}
EF / PV_{AoV}	P = 0.063, r = 0.995	P = 0.167, r = -0.966
EF / MV_{AoV}	P = 0.087, r = 0.991	P = 0.143, r = -0.975
EF / PPG_{AoV}	P = 0.040, r = 0.998	P = 0.189, r = -0.956
EF / MPG_{AoV}	P = 0.063, r = 0.995	P = 0.167, r = -0.966

Table V. The correlation of IAVA and MPG_{AoV} with $EFVR_S$ in subgroup of 65% < EF ≤ 75%.

65% ≤ EF ≤ 75%, N=18	IAVA	MPG_{AoV}
EF / PV_{AoV}	P = 0.047, r = 0.474	P=0.000, r = -0.907
EF / MV_{AoV}	P = 0.044, r = 0.479	P=0.000, r = -0.947
EF / PPG_{AoV}	P = 0.060, r = 0.452	P=0.000, r = -0.822
EF / MPG_{AoV}	P = 0.058, r = 0.455	P=0.000, r = -0.901

Table VI. The correlation of IAVA and MPG_{AoV} with $EFVR_S$ in subgroup of 75% < EF ≤ 85%.

75% < EF ≤ 85%, N=30	IAVA	MPG $_{AoV}$
EF / PV_{AoV}	P = 0.000, r = 0.663	P = 0.000, r = -0.870
EF / MV_{AoV}	P = 0.000, r = 0.641	P = 0.000, r = -0.914
EF / PPG_{AoV}	P = 0.000, r = 0.689	P = 0.000, r = -0.760
EF / MPG_{AoV}	P = 0.000, r = 0.675	P = 0.000, r = -0.821

Table VII. The correlation of IAVA and MPG_{AoV} with $EFVR_S$ in subgroup of EF >85%.

85% < EF , N=6	IAVA	MPG $_{AoV}$
EF / PV_{AoV}	P = 0.007, r = 0.933	P = 0.002, r = -0.961
EF / MV_{AoV}	P = 0.015, r = 0.897	P = 0.004, r = -0.951
EF / PPG_{AoV}	P = 0.009, r = 0.920	P = 0.004, r = -0.950
EF / MPG_{AoV}	P = 0.011, r = 0.912	P = 0.006, r = -0.938

Discussion

Studies of left ventricular performance in children with aortic stenosis (AS) often indicate that supernormal pump function exists, as indicated by an increase in ejection fraction.[1] Undoubtedly a spectrum exists, from well-compensated patients at one extreme, who have supernormal pump function and normal contractile function, to patients with heart failure at the opposite extreme, who have both impaired pump function and reduced contractile state.[1,14]

If we have two patients of aortic valve stenosis , the first with EF = 80% and PPG = 100mmHg and the second one with EF = 50% and PPG = 60mmHg, their EF / PPG_{AoV} will be 0.0080 and 0.0083, respectively. It shows that the PPG of the second patient is much lower than that of the first one, which may be thought to be related to the non-severity of his or her AS. Nonetheless, we can assume that the second patient may be the first whose pressure gradient has decreased, and that this decrease will result in a decreased EF.

Our study was based on the role of EF in the determination of the severity of aortic valve stenosis.

In the two subgroups of EF ≤ 65% and >85%, an inadequate number of patients made a significant statistical evaluation impossible. But in the subgroups of 65% < EF ≤ 75% and 75% < EF ≤ 85%, the correlation of mean pressure gradient with EFVRs was inversely related (P<0.01). The correlation rate of EF/PPG_{AoV} was slightly lower than that of the other EFVRs in the two groups. The correlation of IAVA with EFVRs in the subgroup of 75% < EF ≤ 85% was significant (P<0.001, r ≥ 0.641, Table VI), which means if EF interferes with the value of the AS severity, it does not necessarily follow that in all of them a reduction in EFVRs will lower IAVAs, because EF may rise but EFVR can remain constant or even increase. So the interfering of EF will lower the correlation quantity overall. However, the correlation of IAVA with MPG_{AoV} was within these ranges in our study too.

The amount of decrease in correlation may be related to the amount of decrease in the correlation between IAVA and MPG_{AoV} and not EFVRS (because our basis was the coordination of IAVA and MPG_{AoV}). In the subgroup of 65% < EF ≤ 75%, there was no correlation between IAVA and EFVRs. But this was not because there was no correlation between MPG_{AoV} and IAVA; they indeed did have good coordination (P<0.001, r= -0.610). The interference of EF should, therefore, be under consideration.

Tables V and VII illustrate that an increase in EF will raise the correlation between IAVA with EFVRs, indicating that the interferece of EF will be effective on the severity of aortic valve stenosis, measured by aortic jet pressure gradient.

As mentioned before, Antonini–Canterin suggested the interference of EF in the amount of pressure gradients across the stenosed aortic valves.[10,11] His study was in adult patients, but our study is in the pediatric population and we suggest using EFVR in children because this index is easy to obtain and more practical in children. However, our study had several limitations. We had a small patient sample, so we were not able to thoroughly judge all of our subgroups in terms of different ranges of EF. Moreover, our inability to perform successful catheterization for all of our patients precluded a comparison between the values of catheterization with echocardiography data. In addition, performing echocardiography on children whose heart beats are rapid and their sizes are small is very difficult, because small mistakes may produce large errors with the values. Al-Ghamdi and colleagues, in an effort to evaluate EFVR in AS patients, concluded that the EFVR was a simple non-invasive method for screening patients for an AVA of 1.0 cm^2. It could be used as a screening test or in lieu of the continuity equation particularly when there is problematic measurement of either the LVOT diameter or velocity.[8] However, before it FSVR proved to be useful in comparison of AVA for evaluating AS severity.[9,15] Their studies were in adult patients too. So with continuing this study, having larger numbers of patients, more successful catheterizations and enough time for sizing their hearts and estimation of their cardiac valve velocities and gradients, we can widely develop the knowledge of evaluating the severity of aortic valve stenosis by echocardiographic EFVR and determine a number and cut-point for creating a limitation between severe and non-severe forms of aortic valve stenosis.

References

1. Allen HD, Gutgesell HP, Clark EB, Driscoll DJ: Doppler Echocardiography, aortic stenisis. In: Moss and Adams' Heart disease in infant, children, and adolescents, including the fetus and young Adults, 6th ed. Lippincott Williams and Wilkins, USA, 2001: pp 245-247, 974.
2. Fischer JL, Haberer T, Dickson D, Henselmann L. Comparison of Doppler echocardiographic methods with heart catheterization in assessing aortic valve area in 100 patients with aortic stenosis. Br Heart J 1995; 73: 293-298.
3. Lemler MS, Valdes-Cruz LM, Shandas RS, Cape EG. Insights into catheter / Doppler discrepancies in congenital aortic stenosis. Am J Cardiol 1999; 83: 1447-1450.
4. Lima VC, Zahn E, Houde C, Smallhorn J, Freedom RM, Benson LN. Non-invasive determination of the systolic peak-to-peak gradient in children with aortic stenosis: Validation of a mathematical model. Cardiol Young 2000; 10(2): 115-119 (Abstract).
5. Bengur AR, Snider AR, Serwer GA, Peters J, Rosenthal A. Usefulness of the Doppler mean gradient in evaluation of children with aortic valve stenosis and comparison to gradient at catheterization. Am J Cardiol 1989; 64(12): 756 (Abstract).
6. Schmalz A, Erbel R, Wittlich N, Mohr-Kahaly S, Meyer J. Noninvasive quantification and classification of the severity of aortic stenosis using Doppler echocardiography. Z Kardiol 1992; 81(11): 619-626.
7. Faggiano, P, Ghizzoni G, Sorgato A, Sabatini T, Simoncelli U, Gardini A: Rate of progression of valvular aortic stenosis in adults. Am J Cardiol 1992 Jul 15; 70(2): 229.
8. Al-Ghamdi AM, Melendez LJ, Massel D. Ejection fraction velocity ratio as an indicator of aortic stenosis severity. Echocardiograph. 2005 Mar; 22(3): 195-202.
9. Mann DL, Usher BW, Hammerman S, Bell A, Gillam LD. The fractional shortening-velocity ratio: validation of a new echocardiographic Doppler method for identifying patients with significant aortic stenosis. Am Coll Cardiol 1990 Jun; 15(7): 1578-1584.
10. Antonini-Canterin F, Pavan D, Burelli C, Cassin M, Cervesato E, Nicolosi GL. Validation of ejection fraction–velocity ratio: a new simplified "function- corrected index" for assessing aortic stenosis severity. Am J Cardiol 2000; 86(4): 427-433.

11. Antonini-Canterin F, Huang G, Cervesato E, Faggiano P, Pavan D, Piazza R, et-al. Reliability of new and old Doppler echocardiographic indexes of the severity of aortic stenosis in patients with a low cardiac output. Ital Heart J 2002; 3(4): 248-255.

12. Otto CM: Cardiomyopathies, hypertensive and pulmonary heart disease. In: Textbook of Clinical Echocardiography, 2nd ed. WB Saunders USA. 2000: p 238.

13. Snider AR, Serwer GA, Ritter SB: Methods for obtaining Quantitative information from the echocardiographic examination, Abnormalities of ventricular outflow. In: Echocardiography in Pediatric Heart Disease, 2nd ed. Mosby USA, 1997: pp 172, 430.

14. Chambers J. Low Gradient, Low Ejection Fraction Aortic Stenosis. Curr Treat Options Cardiovasc Med 2003 Dec; 5(6): 469-474.

15. Karpuz H, Ozsahin M, Aebischer N, Goy JJ, Kappenberger L, Jeanrenaud X. Usefulness of the echocardiographic velocity ratio for detection of significant aortic stenosis. Am J Cardiol 1999 Nov 1; 84(9): 1101-1103, A10.