Original Article

Quantification of Aortic Regurgitation Severity by Left Ventricular to Right Ventricular Stroke Volume Ratio

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Abstract

Background: *Echocardiography is the most common test used for the evaluation of aortic regurgitation (AR). However, the role of echocardiography as an available and inexpensive method in the quantification of AR by the left ventricle to right ventricle stroke volume ratio (LV/RV SV ratio) has not been completely investigated.*

Methods: *Between June 2005 and December 2007, 132 consecutive patients with AR (mean age: 44.7±14.6 years, 52.3% male) were enrolled in the study. All the patients underwent echocardiography; and aortography, if indicated, was performed as well.*

Results: *Fifty-two percent of the patients had severe AR. There was almost a perfect agreement between echocardiography and cardiac catheterization in determining the severity of AR (Kappa=0.81). Associated valvular disease was found in 81.8% of the patients, the most common disease being mitral regurgitation (61%). The results of our bivariate and multivariate analyses showed a significant relation between the LV/RV SV ratio and the AR severity via either echocardiography or cardiac catheterization (both P=0.001). The receiver operating characteristic (ROC) curve analysis showed that the LV/RV SV ratio was very accurate in the detection of severe AR utilizing cardiac catheterization as the gold standard (AUC=0.71). The cut point value of the LV/RV SV ratio ≤1.5 had a sensitivity of 56% and specificity of 75% for the differentiation of non-severe from severe AR.*

Conclusion: *Our study demonstrated that the LV/RV SV ratio was a simple and reliable method for the assessment of the severity of AR. This method is more accurate in the absence of a significant involvement of the other valves.*

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Keywords: *Aortic valve • Stroke volume • Echocardiography*

Introduction

Hemodynamically severe aortic regurgitation (AR) is the most predictable cause of heart failure and sudden death.[1] Non-invasive methods have been developed over the years for an objective assessment of the severity and cardiac size and function.[2]

The most common test used for the evaluation of the severity of AR is echocardiography. The simplest methods are based on the visual assessments of the regurgitant jet, using color flow mapping. These include the area of the jet relative to the area of the left ventricular outflow tract (LVOT); the width of the jet relative to the width of the LVOT; the width of the jet at its narrowest point (just beyond the regurgitant orifice), termed the "vena contracta";[3] and the pressure half time (the time taken for the peak gradient to fall by 50%), which is assessed by the measurement of the slope of the regurgitant continuous wave Doppler signal.

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This study sought to determine the severity of AR by the quantification of the left ventricle to right ventricle stroke volume ratio (LV/RV SV ratio).

Methods

Between 2005 and 2008, 132 consecutive patients with AR were enrolled in this study. The inclusion criteria were patients with either isolated AR or in combination with other valve involvement. Sixty-nine patients with severe and moderate to severe, 36 patients with moderate, and 27 patients with mild and mild to moderate AR were studied. The mean age of the patients was 44.7±14.6 years (range: 16-78), and men accounted for 52.3% of the study population. The etiology of AR was rheumatic in 75 (57%), congenital in 15(11.4%), aortic aneurysm in 24(18.2%), endocarditis in 8 (6%), dissection in 3 (2.3%), and other etiologies in 7 (5.7%) patients.

All the participants underwent a clinical examination, 12-lead electrocardiography (ECG), and complete transthoracic echocardiography. In addition, if indicated, aortography was also conducted.

AR severity was assessed via 2D, M-mode, and Doppler echocardiography and was graded in accordance with the guidelines of the American Society of Echocardiography[3-6] (Table 1).

Table 1. Quantification of Doppler parameters for grading the AR severity

	Mild	Moderate		Severe
VC width (cm)	<0.3	0.3-0.6		>0.6
Jet width/LVOT width (%)	<25	25-45	46-64	≥65
Jet area /LVOT area (%)	<5	5-20	21-59	≥60
RV (ml/beat)	<30	30-44	45-59	≥60
RF (%)	<30	30-39	40-49	≥50
EROA (cm^2)	<0.10	0.10-0.19	0.20-0.29	≥0.30

AR, Aortic regurgitation; VC, Vena contracta; LVOT, Left ventricular outflow tract; RV, Regurgitant volume; RF, Regurgitant fraction; EROA, Effective regurgitant orifice area

The systemic and pulmonary flows were derived with the continuity equation method.[4] The LV/RV SV ratio was determined and compared with the angiographic data if available. Cardiac catheterization was carried out with at least 6 hours' fasting. Oral sedation (5 mg diazepam and 25 mg promethazine) was administered in all the patients. Hemodynamic measurements were made before angiocardiography. The severity of AR was generally graded through visual assessment by determining the relative amount of the radiographic contrast medium that opacified the LV and was classified as the Sellers classification from +1 to +4.

The statistical analyses were conducted using SPSS-13 (Chicago, IL, USA) and STATA for Windows. The continuous variables are presented as mean±standard deviations (SD), and the categorical data are expressed as frequencies. The weighted Kappa index was used to assess agreement. The comparison of the differences between the groups was made using the paired samples t-test. Multiple comparisons were performed employing the independent samples t-test and one-way ANOVA. A difference was considered significant when the probability value was <0.05. Diagnostic accuracy was calculated using the receiver operating characteristic (ROC) curve. The sensitivity and specificity of the LV/RV SV ratio for determining the severity of AR was calculated by using the result of cardiac catheterization as the gold standard. Furthermore, 95% confidence interval for each variable was computed. Intra-observer variability was assessed for LVOT and RVOT diameters and velocity time integral. Twenty patients were selected randomly, and two measurements were taken for each patient. Intra-observer variability was defined as the differences between the measurements and was expressed as a percentage error of the means.

Results

The baseline characteristics of the patients are shown in Table2. Cardiac catheterization was done in 62% of the patients.

For clinical implications, the patients were divided into two groups: Group I with no significant valvular disease consisting of the patients with mild, mild to moderate, and moderate degrees of valve stenosis or regurgitation and Group II comprising patients with moderate to severe and severe valvular diseases.

Table 2. Baseline characteristics of the patients (n=132)

Age (y) (mean±SD)	44.7±14.65
Male (%)	69 (52.3)
EF (%) (mean±SD)	46±10
[e]AR (%)	
Mild	4.5
Mild-moderate	15.9
Moderate	27.3
Moderate-severe	17.4
Severe	34.8
[c]AR (%)	
+1	11
+2	29.3
+3	29.3
+4	30.5

EF, Ejection fraction; AR, Aortic regurgitation, [e]AR, Grading of aortic regurgitation by echocardiography; [c]AR, Grading of aortic regurgitation by cardiac catheterization

Less than half (41.7%) of the patients had mitral stenosis, which was severe in most of them (31%). The mean mitral valve area was 0.96±0.29 cm^2. In contrast to cases with mitral stenosis, the majority of the patients with mitral regurgitation, tricuspid regurgitation, and pulmonary insufficiency had non-severe degrees of valvular involvement (Table 3).

Table 3. Associated valvular disease in the study patients*

Valve disease	Non-severe	Severe
AR (100)	48	52
AS (22.7)	10.6	12.1
MR (60.6)	50.5	10.1
MS (41.7)	10.7	31
TR (48.5)	41.7	6.8
TS (3)	3	0
PI (12)	10.5	1.5

*Numbers are presented as the related percentage
AR, Aortic regurgitation; AS, Aortic stenosis; MR, Mitral regurgitation; MS, Mitral stenosis; TR, Tricuspid regurgitation; TS, Tricuspid stenosis; PI, Pulmonary insufficiency

There was almost a perfect agreement between echocardiography and cardiac catheterization in determining the severity of valvular abnormality (Kappa=0.81).

The bivariate analysis showed no significant relation between the LV/RV SV ratio and age (P=0.7), but a significant positive relation was found between the LV/RV SV ratio and sex (P=0.008) and the other echocardiographic indices of the AR severity.

There was a significant relation between the mean LV/RV SV ratio and the AR severity via either echocardiography or cardiac catheterization (both P=0.001) (Table 4).

Table 4. Comparison of LV/RV SV ratio in patients with AR according to echocardiography and cardiac catheterization

AR grading		LV/RV SV ratio (mean±SD)		
Echocardiography	Catheterization	Echo	Cath	P value
Mild	+1	1.19±0.23	1.15±0.30	NS
Mild-moderate	+2	1.38±0.31	1.45 ±0.67	NS
Moderate		1.45±0.71		
Moderate-severe	+3	1.68±0.71	1.69±0.70	NS
Severe	+4	2.4±1.1	2.37±0.96	NS

LV/RV SV ratio, The mean left ventricular to right ventricular stroke volume ratio; AR, Aortic regurgitation; Echo, Echocardiography; Cath, Catheterization; NS, Not significant

For clinical implications, the patients were classified into two groups: Group I was comprised of the patients with mild, mild to moderate, and moderate AR (n=63) and Group II consisted of the patients with moderate to severe and severe AR (n=69). The mean LV/RV SV ratio was significantly higher in Group II patients (2.06 vs. 1.42, respectively; P<0.001) (Table 5).

The multivariate analysis showed a significant positive relation between the LV/RV SV ratio and sex (P=0.04) and a significant negative relation between the LV/RV SV ratio and mitral valve stenosis (P=0.002) (Table 6).

No significant relation was found between the LV/RV SV ratio and aortic stenosis (P=0.83). The mean LV/RV SV ratio was lower in the patients with severe mitral regurgitation, tricuspid regurgitation, and pulmonary insufficiency; however, this difference was not statistically significant (P=0.15, 0.1 and 0.21, respectively).

The multivariate analysis using an ordinal logistic regression model demonstrated a significant positive relation between the LV/RV SV ratio with AR and mitral stenosis severity (OR=2.72, P=0.006 and OR=0.74, P=0.015; respectively) (Table 6).

Table 5. Comparison of LV/RV SV ratios between the two groups

Severity AR	LV/RV SV ratio (mean±SD)
Group I (n=63)*	1.42
Group II (n=69)**	2.06
P value	<0.001

*Non-severe aortic regurgitation
**Severe aortic regurgitation
LV/RV SV ratio, The mean left ventricular to right ventricular stroke volume ratio; AR, Aortic regurgitation

Table 6. Multivariate analysis between LV/RV SV ratio and other variables

	Coef	SD	P	OR	Confidence Interval (95%)
LV/RV SV ratio	1.00	±0.36	0.01	2.72	1.33-5.55
EF	0.01	±0.02	0.97	1.00	0.95-1.05
MS	-0.28	±0.11	0.01	0.74	0.59-0.94
TR	-0.11	±0.17	0.51	0.89	0.63-1.25
PI	-0.28	±0.26	0.21	0.75	0.45-1.25
MR	-0.20	±0.17	0.22	0.81	0.58-1.13
Sex	-1.04	±0.52	0.04	0.35	0.12-0.97

LV/RV SV ratio, The mean left ventricular to right ventricular stroke volume ratio; Coef, Coefficient; SD, Standard deviation; P, Probability value; OR, Odds ratio; EF, Ejection fraction; MS, Mitral stenosis; TR, Tricuspid regurgitation; PI, Pulmonary insufficiency; MR, Mitral regurgitation

Considering the LV/RV SV ratio as a numerical index, the ROC curve analysis showed that the LV/RV SV ratio was very accurate in the detection of severe AR utilizing cardiac catheterization as the gold standard (AUC=0.71) (Figure 1). The cut point value of LV/RV SV ratio ≤1.5 had a sensitivity of 56% and specificity of 75% for the differentiation of non-severe from severe AR (Table 7).

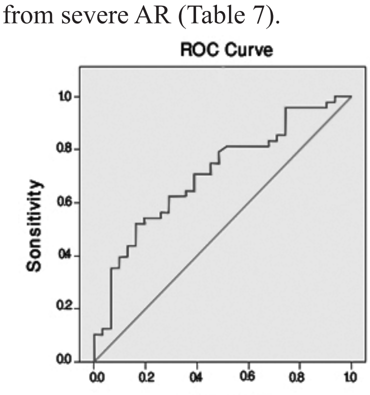

Figure 1. (ROC) curve analysis of LV/RV SV ratio for detection of severe AR regarding cardiac catheterization (AUC=0.71, CI=95%)

Table 7. Comparison of sensitivity and specificity of different cut points of LV/RV SV ratio

Cut point	Sensitivity	Specificity
1.35	0.62	0.68
1.36	0.62	0.71
1.38	0.60	0.71
1.39	0.58	0.71
1.43	0.56	0.71
1.50	0.56	0.75
1.54	0.54	0.75
1.56	0.54	0.78
1.59	0.54	0.81
1.60	0.52	0.81

LV/RV SV, The mean left ventricular to right ventricular stroke volume ratio

The mean differences for the intra-observer variability were 6.2% for 2D and 4.8% for Doppler measurements.

Discussion

Echocardiography is the clinical standard for the evaluation of valvular regurgitation and provides useful information on the AR severity and LV function.[5] Be that as it may, the role of echocardiography as an available and inexpensive method for the quantification of AR through the LV/RV SV ratio has not been studied previously. When echocardiography images are suboptimal or there is a discrepancy between the clinical data and the echocardiographic findings, other invasive (aortography) or non-invasive (radionuclide angiography) imaging modalities are necessary for the estimation of the AR severity.

Radionuclide angiography provides an accurate non-invasive assessment of the AR severity by determining the regurgitant fraction and of the LV/RV SV ratio, but it is costly and has yet to gain worldwide acceptance.

In a study by Urquhart et al. using radionuclide angiography, patients with AR had a significantly higher LV/RV SV ratio compared to patients without AR (3.91±1.45 vs. 1.32±0.15, respectively).[7] In another study by Klepzig et al.,[8] effective and total LV stroke volume were assessed in 31 patients with aortic or mitral regurgitation, or both, using combined first-pass and equilibrium radionuclide ventriculography. The mean LV/RV SV ratio in patients with +4, +3, +2, and +1 AR was 3.85, 2.8, 2.01, and 1.60 respectively. The authors in question showed that the LV/RV SV ratio had a sensitivity of 87% and specificity of 100% in detecting the AR severity. They found that right-sided heart failure, functional tricuspid regurgitation, and pulmonary insufficiency reduced this ratio; and because of RV volume overload in 5 patients, only a weak correlation could be noticed between angiography and the LV/RV stroke count ratio (r=0.47, P<0.05).[8] In our study, the cut point value of LV/RV SV ratio ≤1.5 had a sensitivity of 56% and specificity of 75% in differentiating non-severe from severe AR. By contrast, we found a good correlation between angiography and the LV/RV SV ratio (r=0.8, P<0.001). These lower sensitivity and specificity compared to those reported by Klepzig et al. may be due to the effects of confounding variables on the ROC curve, which were not adjusted in our study. We found a significant negative relation between the LV/RV SV ratio with mitral stenosis (P=0.01); we, nonetheless, observed no significant relation between the LV/RV SV ratio and mitral regurgitation, tricuspid regurgitation, and PI. This result may be related to the severe degree of mitral stenosis compared to milder degrees of the other valvular abnormalities in our patients (Table 2). Our results were very similar to those in the Borer et al. study, which found LV/RV SV ratio ≥2.0 as a marker of significant AR.[1]

The result chimes in with our findings in that we found a LV/RV SV ratio >2.06 to be a marker of significant AR.

Conclusion

Our study demonstrated that the LV/RV SV ratio was a simple and reliable method for the assessment of the severity of AR. This method is more accurate in the absence of a significant involvement of the other valves.

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