Table 4 Qualitative and quantitative parameters useful in grading aortic regurgitation severity

	Mild	Moderate		Severe
Structural parameters				
LA size	Normal*	Normal or dilated		Usually dilated**
Aortic leaflets	Normal or abnormal	Normal or abnormal		Abnormal/flail, or wide coaptation defect
Doppler parameters				
Jet width in LVOT –Color Flow[ζ]	Small in central jets	Intermediate		Large in central jets; variable in eccentric jets
Jet density–CW	Incomplete or faint	Dense		Dense
Jet deceleration rate –CW (PHT, ms)[ψ]	Slow > 500	Medium 500-200		Steep < 200
Diastolic flow reversal in descending aorta –PW	Brief, early diastolic reversal	Intermediate		Prominent holodiastolic reversal
Quantitative parameters[φ]				
VC width, cm[ζ]	< 0.3	0.3-0.60		> 0.6
Jet width/LVOT width, %[ζ]	< 25	25-45	46-64	≥ 65
Jet CSA/LVOT CSA, %[ζ]	< 5	5-20	21-59	≥ 60
R Vol, 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; *CSA*, cross sectinal area; *CW*, continuous wave Doppler; *EROA*, effective regurgitant orifice area; *LV*, left ventricle; *LVOT*, left ventricular outflow tract; *PHT*, pressure half-time; *PW*, pulsed wave Doppler; *R Vol*, regurgitant volume; *RF*, regurgitant fraction; *VC*, vena contracta.

* Unless there are other reasons for LV dilation. Normal 2D measurements: LV minor axis ≤ 2.8 cm/m^2, LV end-diastolic volume ≤ 82 ml/m^2 (2).

** Exception: would be acute AR, in which chambers have not had time to dilate.

ζ At a Nyquist limit of 50–60 cm/s.

ψ PHT is shortened with increasing LV diastolic pressure and vasodilator therapy, and may be lengthened in chronic adaptation to severe AR

φ Quantitative parameters can sub-classify the moderate regurgitation group into mild-to-moderate and moderate-to-severe regurgitation as shown.

b. Pulsed Doppler quantitative flow methods. PW Doppler recordings of flow velocity can be combined with 2D measurements to derive flow rates and stroke volume.[13] The technical details involved in making these measurements and their sources of error are described in the document on Quantitation of Doppler Echocardiography.[3] This method is simple in theory but accurate results require individual training (e.g. practice in normal patients where the stroke volumes at different sites are equal). Briefly, stroke volume (SV) at any valve annulus–the least variable anatomic area of a valve apparatus- is derived as the product of cross sectional area (CSA) and the velocity time integral (VTI) of flow at the annulus. Assumption of a circular geometry has worked well clinically for most valves with the exception of the tricuspid annulus. Thus,

$$SV = CSA \times VTI = \pi d^2/4 \times VTI = 0.785\ d^2 \times VTI$$

where d is the diameter of the annulus. Calculations of stroke volume can be made at two or more different sites—left ventricular outflow tract (LVOT), mitral annulus, and pulmonic annulus. In the absence of regurgitation, stroke volume determinations at these sites are equal. In the presence of regurgitation of one valve, without any intracardiac shunt, the flow through the affected valve is larger than through other competent valves. The difference between the two represents the regurgitant volume.[14,15] Regurgitant fraction is then derived as the regurgitant volume divided by the forward stroke volume through the regurgitant valve. Thus,

$$\text{Regurgitant Volume} = SV_{RegValv} - SV_{CompValv}$$

$$\text{Regurgitant Fraction} = (SV_{RegValv} - SV_{CompValv})/SV_{RegValv}$$

where $SV_{RegValv}$ is stroke volume derived at the annulus of the regurgitant valve and $SV_{CompValv}$ is the stroke volume at the competent valve. Effective regurgitant orifice area can be calculated similar to the PISA method as regurgitant volume divided by the velocity time integral of the regurgitant jet velocity (VTI_{RegJet}) recorded by CW Doppler as:

$$\text{EROA} = \text{Regurgitant Volume}/VTI_{RegJet}$$

The most common errors encountered in determining these parameters are 1) failure to measure the valve annulus properly (error is squared in the formula), 2) failure to trace the modal velocity (brightest signal representing laminar flow) of the pulsed Doppler tracing and 3) failure to position the sample volume correctly, and with minimal angulation, at the level of the annulus. Furthermore, in the case of significant calcifications of the mitral annulus and valve, quantitation of flow at the mitral site is less accurate and more prone to errors.

In left sided regurgitant lesions, $SV_{RegValv}$ or total stroke volume of the ventricle can also be measured using left ventricular volume calculations by 2D echocardiography as end-diastolic volume minus end-systolic volume. Methods for calculation of left ventricular volumes have been previously detailed.[2] Measurement of left ventricular volumes by echocardiography has the potential pitfall of underestimating true left ventricular volume and therefore underestimating regurgitation severity. Recently, the use of intravenous contrast agents that cross the pulmonary circulation has shown promise in facilitating the tracing of the ventricular endocardium and improving the accuracy and reproducibility of volume measurements.[16,17] Assessment of ventricular volumes based on M-mode echocardiography has important limitations and is not recommended.