Table 1 Qualitative and quantitative parameters useful in grading mitral regurgitation severity

	Mild	Moderate		Severe
Structural parameters				
LA size	Normal*	Normal or dilated		Usually dilated**
LV size	Normal*	Normal or dilated		Usually dilated**
Mitral leaflets or support apparatus	Normal or abnormal	Normal or abnormal		Abnormal/ Flail leaflet/ Ruptured papillary muscle
Doppler parameters				
Color flow jet area[ξ]	Small, central jet (usually < 4 cm^2 or $< 20\%$ of LA area)	Variable		Large central jet (usually > 10 cm^2 or $> 40\%$ of LA area) or variable size wall-impinging jet swirling in LA
Mitral inflow –PW	A wave dominant[φ]	Variable		E wave dominant[φ] (E usually 1.2 m/s)
Jet density –CW	Incomplete or faint	Dense		Dense
Jet contour –CW	Parabolic	Usually parabolic		Early peaking–triangular
Pulmonary vein flow	Systolic dominance[§]	Systolic blunting[§]		Systolic flow reversal†
Quantitative parameters[ψ]				
VC width (cm)	< 0.3	0.3-0.69		≥ 0.7
R Vol (ml/beat)	< 30	30-44	45-59	≥ 60
RF (%)	< 30	30-39	40-49	≥ 50
EROA (cm^2)	< 0.20	0.20-0.29	0.30-0.39	≥ 0.40

CW, Continuous wave; *LA*, left atrium; *EROA*, effective regurgitant orifice area; *LV*, left ventricle; *PW*, pulsed wave; *RF*, regurgitant fraction; *R Vol*, regurgitant volume; *VC*, vena contracta.

* Unless there are other reasons for LA or LV dilation. Normal 2D measurements: LV minor axis ≤ 2.8 cm/m^2, LV end-diastolic volume ≤ 82 ml/m^2, maximal LA antero-posterior diameter ≤ 2 cm/m^2, maximal LA volume ≤ 36 ml/m^2 (2,33,35).

** Exception: acute mitral regurgitation.

ξ At a Nyquist limit of 50–60 cm/s.

† Pulmonary venous systolic flow reversal is specific but not sensitive for severe MR.

φ Usually above 50 years of age or in conditions of impaired relaxation, in the absence of mitral stenosis or other causes of elevated LA pressure.

§ Unless other reasons for systolic blunting (eg. atrial fibrillation, elevated left atrial pressure).

ψ Quantitative parameters can help sub-classify the moderate regurgitation group into mild-to-moderate and moderate-to-severe.

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.