C. MITRAL REGURGITATION

1. Role of Two-dimensional Echocardiography

Evaluation of the anatomy of the mitral valve apparatus by 2D echocardiography is critically important in the assessment of severity of mitral regurgitation (MR). The mitral apparatus includes the leaflets, chordae tendineae, annulus, and the papillary muscles with their supporting left ventricular (LV) walls. Careful evaluation of these structures should be able to define the mechanism of MR and yield clues to its severity. For example, a prominent flail leaflet is usually associated with severe MR. On the other hand, severe MR rarely occurs in the setting of an anatomically normal mitral valve and support apparatus. Defining the mechanism of MR may determine whether valve repair is feasible instead of valve replacement.[29,30] In patients with MR in the setting of LV dilatation and/or systolic dysfunction, it is important to determine whether MR is functional (i.e. due to LV dilatation) or primary (i.e. due to an abnormality of the valve apparatus). In functional MR, the leaflets are usually tethered by outward displacement of the LV walls and papillary muscles, with or without annular dilation.[31] Underlying wall motion abnormalities in patients with coronary artery disease may also lead to functional MR. Finally, evaluation of left atrial (LA) size and LV size and function provides clues to the severity of MR, its acuteness or chronicity, and are important in determining the necessity and timing of surgery.[1,32] Normal 2D- derived values for left ventricular size and function have been previously reported.[2] Briefly, the end-diastolic minor axis dimension of the LV obtained from the parasternal window by 2D is normally $\leq$ 2.8 cm/m^2 while the normal end-diastolic LV volume is $<$ 82 ml/m^2.[2] For the left atrium, a normal antero-posterior diameter is $\leq$ 2 cm/ m^2.[33] Recent studies however have shown that determination of LA volumes with 2D echocardiography from the apical views is generally more accurate in assessing LA size than the traditional antero-posterior dimension.[34] A normal maximal LA volume is $\leq$ 36 ml/m^2.[35]

2. Doppler Methods

a. Color flow Doppler. Color Doppler flow mapping is widely used to screen for the presence of

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$^{\zeta}$	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$^{\phi}$	Variable	E wave dominant$^{\phi}$ (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$^{\Psi}$			
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.

$^{\zeta}$ At a Nyquist limit of 50–60 cm/s.

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

$^{\phi}$ 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).

$^{\Psi}$ Quantitative parameters can help sub-classify the moderate regurgitation group into mild-to-moderate and moderate-to-severe.

mitral regurgitation. Importantly, small color flow jets are seen in roughly 40% of healthy normal volunteers and therefore are considered a normal variant.[36] The incidence of mild regurgitation tends to increase with age. The terms trace MR or MR closing volume have been applied to these jets. There are three methods of quantifying MR severity by color flow Doppler mapping: regurgitant jet area, vena contracta, and flow convergence (PISA). Although jet area was the first method used for assessing MR severity, its sole use is less accurate than the latter two methods.

Regurgitant jet area. As a general rule, large jets that extend deep into the LA represent more MR than small thin jets that appear just beyond the mitral leaflets. However, the correlation between jet area and MR severity is poor due to a variety of technical and hemodynamic limitations as noted earlier.[4] Patients with acute severe MR, in whom blood pressure is low and LA pressure is elevated may have a small eccentric color flow jet area, whereas hypertensive patients with mild MR may have a large jet area. Furthermore, the same regurgitant flow will produce larger or smaller jets depending on the size of the atrium, which has led to indexing for atrial area.[37] Finally, color flow jets that are directed centrally into the LA generally appear larger because they entrain red blood cells on all sides of the jet. In contrast, eccentric jets that hug the LA wall cannot entrain blood on all sides and tend to appear smaller than central jets of similar or lesser severity (Figure 3).[38-40] Because of these considerations, determination of the severity of MR by "eyeballing" or planimetry of the MR color flow jet area only, is not recommended. Nevertheless, small, non-eccentric jets with an area < 4.0 cm^2 or $< 20\%$ of LA area are usually trace or mild MR (Table 1). Conversely, large jets that penetrate into the pulmonary veins are more likely to be hemodynamically significant. However, the detection of eccentric, wall-impinging jets should alert the observer to avoid the use of jet area as an index of severity and use other, more appropriate methods described below.