

Case Based Studies in CMR – Valvular Heart Disease
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In adults, valvular heart is the most common form of cardiovascular disease, exceeding even the prevalence of ischemic heart disease. While most patients with valvular heart disease do not require a mechanical intervention, monitoring for disease progression is commonly performed. Left heart valvular disease (aortic and mitral valve dysfunction) is more prevalent than right sided lesions, though right sided disease is increasing seen in patients with complex congenital heart disease.

When considering patients with valvular heart disease for both diagnosis and management, multiple issues are involved, including

- a. Valve morphology – leaflet #, thickening, prolapse, vegetations/abscess
- b. Valvular regurgitation
- c. Valvular stenosis
- d. Impact of valvular lesion on cardiac chambers and function – atrial/ventricular dilation, hypertrophy, fibrosis, and systolic function

The dominant clinical tool for initially identifying and monitoring patients with suspected valvular heart disease is surface/transthoracic echocardiography. Current AHA/ACC Valvular Heart disease guidelines are heavily aligned with echocardiographic anatomic and Doppler metrics for surgical indications and for guiding the frequency of monitoring. Most of these measures can be readily “converted” to CMR metrics, but this conversion fails to take advantage for the fundamental quantitative advantage of CMR with regards to quantification of blood flow and cardiac anatomy/volume. Echocardiographic metrics often are unidimensional for assessment of left ventricular cavity size (e.g., end-diastolic dimension) rather than volumetric methods which are readily obtained by CMR and provide unique measures such as effective forward ejection fraction. Thus, the quantitative volumetric advantage of CMR is currently underutilized. More commonly, CMR is clinically employed to confirm abnormalities for patients with inconsistent symptoms and echocardiographic findings, or for monitoring patients with poor echocardiographic windows.

CMR Sequences:

CMR sequences used in the assessment of valvular heart disease include

1. Cine steady state free precession
 - a. Valvular level: leaflet mobility, valve area, leaflet thickening
 - b. Short-axis LV/RV stack: biventricular volumes, mass, systolic function
2. Phase velocity imaging
 - a. Velocity across the valves

- i. Convert to pressure using the modified Bernoulli formula:
 - 1. Pressure gradient = $4 v^2$
 - ii. Pressure half-time (mitral stenosis).
 - b. Quantification of valvular regurgitation
- 3. Late gadolinium enhancement (LGE)
 - a. Fibrosis (myocardium in aortic stenosis; papillary muscles in MVP)

Common Valvulopathies:

Aortic Stenosis:

The normal aortic valve area is 3-4cm². The severity of aortic stenosis is considered mild with valve areas of 1.2-1.9cm², moderate with 1.0-1.2cm², and severe if <1.0cm². Indications for valve replacement surgery include severe aortic stenosis with symptoms (exertional angina, syncope, congestive heart failure) as well as depressed left ventricular systolic function. Transthoracic Doppler echocardiography is highly quantitative in characterizing aortic valve gradients. Though echocardiography is often suboptimal in defining leaflet morphology in patients with markedly deformed valves, treatment of aortic stenosis is largely independent of valve morphology.

CMR assessment of aortic valve morphology (bicuspid vs. tricuspid) and valve area is performed with cine SSFP CMR at the level of the valve. Valve area can also be defined using a modified Continuity Equation analogous to echocardiographic methods. Both the cine and modified Continuity Equation approaches correlate well with Doppler echocardiographic methods.

Since reduction in left ventricular systolic function is also indication for surgical intervention, quantitative CMR methods to assess left ventricular systolic function also plays an important role in monitoring asymptomatic patients.

More recently, LGE CMR methods have demonstrated mid-wall hyperenhancement in patients with hypertrophy and aortic stenosis. This clinical impact of this imaging finding remains to be more fully elucidated.

Aortic Regurgitation:

While Doppler echocardiographic methods are quite quantitative for assessing valvular stenoses, they are less robust when quantifying valvular regurgitation – an area where CMR has a distinct advantage. Indications for surgical replacement include congestive heart failure, depressed left ventricular systolic function, and left ventricular cavity enlargement thresholds.

CMR methods for quantifying aortic regurgitation include older methods of biventricular cine SSFP of the ventricles with a difference in right ventricular and left ventricular stroke volumes as well as more sophisticated phase velocity mapping methods. The latter are particularly quantitative with highly accurate and reproducible semi-automated analysis tools now widely available. Aortic regurgitant fraction

correlation with color flow Doppler echocardiographic methods are mild (5-15%), moderate (16-25%), moderate to severe (25-48%), and severe (>48%).

Mitral Stenosis:

The normal mitral valve area is 4-6cm². As with the aortic valve, there is tremendous reserve. Mitral stenosis severity is considered mild with valve areas of 1.5-1.9cm², moderate with 1.0-1.5cm², and severe if <1.0cm². Indications for valve surgery include severe mitral stenosis with symptoms of heart failure, recurrent thromboembolism, pulmonary artery hypertension, and development of atrial fibrillation.

CMR methods for assessing mitral stenosis include cine SSFP cine methods to assess leaflet thickening and mobility as well as valve area from 2D planimetry (analogous to 2D echocardiographic and cardiac CT methods). In addition, phase velocity mapping across the mitral valve at the level of the leaflet tips, with application of Pressure ½ time methodology correlates well with Doppler echocardiographic methods.

Mitral Regurgitation:

Like, aortic regurgitation, CMR “shines” in the quantitative assessment of mitral regurgitation. Doppler echocardiographic methods for assessing valvular regurgitation are most often qualitative. Though quantitative echocardiographic methods exist, they are often difficult to apply in patients with eccentric regurgitant jets or poor acoustic windows. CMR methods for assessing mitral regurgitation predominantly involve two approaches.

- a. Cine left and right ventricular stroke volume with the difference being the mitral regurgitant volume (presuming no aortic, pulmonic, and tricuspid regurgitation).
- b. A hybrid solution in which aortic forward flow (determined from phase velocity data at the level of the proximal ascending aorta) is subtracted from left ventricular stroke volume determined from cine SSFP short axis datasets. Similar best correlation thresholds have been identified for comparison with echocardiography for mild, moderate, moderate to severe, and severe regurgitation. A relatively unique metric, effective forward ejection fraction can also be readily determined.

Cine CMR methods can also be used to identify mitral valve prolapse (including scallop prolapse) while LGE CMR methods have preliminarily identified fibrosis at the tips of the papillary muscles as a marker for increased ventricular ectopy in these patients.