Advanced Imaging of Mitral Valve Disease

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Abstract

Mitral valve dysfunction is the most common cause of valvular disease in the US. Although echocardiography is the primary non-invasive modality for visualizing the mitral valve, advances in technology have allowed improved evaluation of mitral disease with magnetic resonance imaging (MRI) and computed tomography (CT). This article will provide an overview of the imaging findings and quantification techniques for mitral regurgitation and mitral stenosis. In addition, the role of MRI and CT in the evaluation of a suspected mass of the mitral apparatus and in the assessment of post-operative complications is discussed.

Keywords

Magnetic resonance imaging, computed tomography, mitral regurgitation, mitral stenosis, mitral mass, mitral surgery

Imaging Technique

Cardiac MRI for valvular assessment requires electrocardiographic gating and breath-held acquisitions. Balanced steady-state free precession (SSFP) sequences in short-axis, two-, three-, and four-chamber views allow for the evaluation of valvular morphology and identification of regurgitant/stenotic jets. If flow velocity across the mitral valve is specifically requested, velocity-encoded cine phase contrast (VENC-PC) images are obtained in a plane perpendicular to mitral blood flow. Post-contrast inversion recovery gradient recalled echo sequences are routinely performed to assess for the presence of late gadolinium myocardial enhancement (LGE).

Cardiac CT angiography is structured to allow for the assessment of coronary arteries and valvular structure and function. Studies are performed after intravenous contrast administration on a multidetector scanner with at least 64-detector-row capacity. Either prospective gating, or retrospective electrocardiographic gating with dose modulation, is used following the 'as low as reasonably allowable' (ALARA) principle. Cine datasets from thin-section reconstructions are used to assess valvular structure and function, viewed primarily as multiplanar reformations with volume rendered and minimum intensity projection images of the valve leaflets as necessary.

Anatomic Considerations

The mitral apparatus consists of an annulus, two valve leaflets, chordae tendineae, and papillary muscles (see Figure 1). The annulus is a ring, shaped like a 'D,' with the straight border comprising the anterior annulus and the curved border comprising the posterior annulus. The anterior mitral leaflet attaches to the straight border of the annulus, which only encompasses about a third of the total annulus area, but nonetheless covers more of the valve orifice than the narrower posterior leaflet. The posterior leaflet attaches to the remaining curved border of the annulus. The mitral valve leaflets are supported by chordae, which in turn attach to two papillary muscles arising from the lateral wall of the left ventricle. Wall motion abnormalities and/or ventricular dilatation can alter tensile forces on the chordae, predisposing to valvular dysfunction.

Mitral Regurgitation

Mitral regurgitation can be either acute or chronic (see Table 1). In acute mitral regurgitation, acute volume loading into the non-compliant left atrium may result in markedly elevated atrial pressure, leading to...
pulmonary edema and heart failure. Acute mitral regurgitation is an uncommon indication for cardiac MRI/CT; however, it may occasionally be detected on chest X-ray or chest CT because of pulmonary edema localized to the right upper lobe.7

In chronic mitral regurgitation, both the left atrium and left ventricle dilate in response to the chronic volume load without necessarily raising pulmonary vascular pressure. However, if the left ventricle decompensates and forward stroke volume decreases, symptoms of heart failure can manifest. Chronic mitral regurgitation is often detected with MRI/CT performed for other purposes, such as pre-operative evaluation of coronary arteries prior to mitral repair. Imaging findings of selected causes of chronic mitral regurgitation are outlined in Table 2.

Mitral valve prolapse (see Figure 2) is a common cause of mitral regurgitation, usually affecting the middle scallop of the posterior leaflet (P2 segment). It is defined as systolic bowing of the mitral leaflet >2mm into the atrium,9 and is most reliably assessed on two- and three-chamber views. Associated imaging findings include leaflet thickening (>5mm) and flail leaflet.9

Flail mitral leaflet (see Figure 3) is defined as eversion of the mitral leaflet tip into the atrium during systole,10 and is due to ruptured chordae tendineae, or less commonly, papillary muscle rupture. Importantly, flail mitral leaflet is associated with severe mitral regurgitation.11

Ischemic cardiomyopathy is another common etiology of mitral regurgitation.12 In this case the valve is normal; however, regional wall motion abnormalities, left ventricle dilatation, and/or annular dilatation cause dysfunction of the mitral apparatus leading to ‘functional’ regurgitation.

Table 1: Selected Causes of Mitral Regurgitation

| Cause                        | Imaging Finding                        | Associated Findings                      |
|------------------------------|----------------------------------------|------------------------------------------|
| Mitral valve prolapse        | Systolic bowing of mitral leaflet >2mm into atrium | Thickened leaflet (>5mm) Flail leaflet |
| Flail leaflet                | Systolic eversion of leaflet tip into atrium       | Severe mitral regurgitation              |
| Ischemic cardiomyopathy      | LV wall motion abnormality               | Late gadolinium enhancement              |
| Hypertrophic obstructive cardiomyopathy | LV dilatation Annular dilatation       | Mural thinning                           |

Table 2: Selected Imaging Findings in Chronic Mitral Regurgitation

| Cause                        | Imaging Finding                        | Associated Findings                      |
|------------------------------|----------------------------------------|------------------------------------------|
| Mitral valve prolapse        | Systolic bowing of mitral leaflet >2mm into atrium | Thickened leaflet (>5mm) Flail leaflet |
| Flail leaflet                | Systolic eversion of leaflet tip into atrium   | Severe mitral regurgitation             |
| Ischemic cardiomyopathy      | LV wall motion abnormality               | Late gadolinium enhancement              |
| Hypertrophic obstructive cardiomyopathy | LV dilatation Annular dilatation | Mural thinning                           |

LV = left ventricular.

In hypertrophic obstructive cardiomyopathy (HOCM), systolic anterior motion (SAM) of the anterior mitral valve leaflet classically results in a posteriorly directed jet of mitral regurgitation (see Figure 4). MRI is typically ordered to assess for myocardial fibrosis13 or to rule out other diseases that can mimic the findings of HOCM, such as infiltrative cardiomyopathy (usually amyloidosis) and athlete’s heart. A left ventricular outflow tract (three-chamber) view is helpful when
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Table 3: Severity of Mitral Regurgitation

| Regurgitant Volume (ml/beat) | Regurgitant Fraction |
|-----------------------------|---------------------|
| Mild                        | <30                 |
| Moderate                    | 30–59               |
| Severe                      | >60                 |

Table 4: Selected Causes of Mitral Stenosis

| Organic Valve Disease          | Non-valvular Disease |
|-------------------------------|----------------------|
| Rheumatic disease             | Ball-valve thrombus  |
| Connective tissue disorders   | Atrial myxoma        |
| Radiation                     |                       |
| Carcinoid                     |                       |
| Valve calcification           |                       |

Figure 3: Dual-source 64-channel Electrocardiographic-gated Computed Tomography After Contrast Injection

Three-chamber systolic image from a 46-year-old female with a thickened posterior leaflet and flail P2 segment (arrow).

Three-chamber diastolic image. Thickened anterior and posterior leaflets (arrows) with commissural fusion/calcification, so-called "fishmouth appearance." (A); Three-chamber diastolic image. Bowing of the thickened anterior leaflet (arrow), so-called "hockeystick appearance." (B).

Figure 4: Electrocardiographic-gated 1.5T Magnetic Resonance Imaging After Contrast Injection

Three-chamber steady-state free precession systolic image from a 62-year-old male with a posteriorly directed dephasing jet of mitral regurgitation (arrow due to hypertrophic obstructive cardiomyopathy. Hypertrophied basal septum (*).
evaluating suspected HOCM because it allows for simultaneous evaluation of SAM of the anterior mitral leaflet, mitral regurgitation, and left ventricle outflow obstruction.

If mitral regurgitation is detected on MRI/CT, the severity can be quantified by calculating the regurgitant volume and regurgitant fraction (see Table 3). In cases of pure mitral regurgitation, the regurgitant volume is equal to the difference between the left and right ventricular stroke volumes, as determined by MRI or CT.14 If mixed valvular disease is present, MRI should be used.15 VENC-PC of the ascending aorta can be used to quantify the volume of forward flow, which is subtracted from the left ventricle stroke volume (by volumetric calculation) to obtain the regurgitant volume.15 Regurgitant fraction is then obtained by dividing the regurgitant volume by the stroke volume.

**Mitral Stenosis**

Rheumatic mitral stenosis is uncommon, but remains the most frequent cause of mitral stenosis in the developed world.1 Selected causes of mitral stenosis are listed in Table 4. Presenting symptoms of mitral stenosis are commonly due to the development of atrial fibrillation and pulmonary vascular hypertension. Symptoms of right ventricular failure may also manifest as a result of prolonged pulmonary vascular hypertension.

In patients with rheumatic mitral stenosis, certain characteristic morphologic changes to the mitral valve may occur.16 Restricted opening of the thickened valve from commissural fusion and/or valve calcification results in a ‘fish-mouth’ appearance on short-axis images (see Figure 5). Diastolic bowing of a thickened and fibrotic anterior leaflet results in a ‘hockey-stick’ appearance (see Figure 5), best seen on the two- or four-chamber view.

Non-valvular causes of mitral obstruction can mimic symptoms of mitral stenosis. For example, ball-valve thrombus and left atrial myxoma (see Figure 6) have well-described MRI and CT features.17,18

Quantifiable parameters of mitral stenosis severity include valve area on planimetry and mean diastolic gradient across the valve on VENC-PC (see Table 5).19–21 Mitral valve area can be determined by drawing a contour around the smallest valve orifice, in a slice obtained perpendicular to the valve plane. To determine the mean diastolic gradient, VENC-PC MRI is performed on a series of images perpendicular to the valve plane, beginning just proximal to the apposition of the stenotic leaflets.20 However, we do not routinely assess the mean diastolic gradient with VENC-PC MRI because it can underestimate the true gradient.22 Secondary signs of mitral stenosis include left atrial enlargement, main pulmonary artery enlargement, and right ventricular enlargement.

**Mitral Masses**

MRI or CT assessment of the mitral valve is often performed to assist in the diagnosis and characterization of a mass detected on echocardiography. The most common mass involving the mitral apparatus is idiopathic mitral annular calcification,23 followed by valvular vegetation from infective endocarditis. Other causes of mitral valve masses, such as neoplasms, are rare (see Table 6). At our institution, cine CT is preferred when imaging a suspected mitral mass because of its superior spatial resolution and lower susceptibility to artifacts.

Although mitral annular calcification is commonly encountered, in certain patients annular calcification undergoes a central degenerative softening leading to caseous degeneration of the mitral annulus (see Figure 7), which may be confused for a neoplasm on echocardiography. This process is usually focal, occurring in the peri-annular region adjacent to the posterior mitral leaflet.24 On CT, caseous degeneration of the mitral annulus appears as a well-defined peripherally calcified non-enhancing mass with a central region of variable hypodensity.24 The MRI appearance can be variable, but it is usually dark on all pulse sequences.

**Table 5: Severity of Mitral Stenosis**

| Valve Area (cm²) | Mean Gradient (mmHg) |
|-----------------|----------------------|
| Normal          | 4–6                  | 0                    |
| Mild            | >1.5                 | <5                   |
| Moderate        | 1–1.5                | 5–10                 |
| Severe          | <1                   | >10                  |

**Table 6: Selected Causes of Mitral Masses**

| Non-neoplastic | Benign Neoplasm | Malignant Neoplasm |
|----------------|-----------------|--------------------|
| Mitral annular calcification | Papillary fibroelastoma | Lymphoma |
| Vegetation (infective>>bland) | Myxoma            | Sarcoma            |
| Caseous degeneration of mitral annulus |                | Metastasis         |
| Thrombus        |                  |                    |

**Figure 6: Sixty-four-channel Computed Tomography After Contrast Injection**

A 45-year-old female with a left atrial myxoma obstructing mitral inflow (*).
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Figure 7: Dual-source 64-channel Electrocardiographic-gated Computed Tomography After Contrast Injection

Short-axis diastolic image from a 62-year-old male with caseous degeneration of the mitral annulus. Within the posterior annulus there is a peripherally calcified mass with central hypointensity (arrowhead). Mitral annular calcification (arrow).

Figure 8: Electrocardiographic-gated 1.5T Magnetic Resonance Imaging After Contrast Injection

Four-chamber diastolic image from a 69-year-old female with mitral valve vegetations from infective endocarditis.

Figure 9: Sixty-four-channel Computed Tomography After Contrast Injection

A 58-year-old female with a paravalvular abscess (*) following mitral valve replacement; the neck originates from the prosthetic mitral valve (arrow).

Figure 10: Dual-source 64-channel Electrocardiographic-gated Computed Tomography After Contrast Injection

Four-chamber image from a 63-year-old female with paravalvular pseudoaneurysm (*) following mitral valve replacement. Mitral annular calcification (arrow).

Figure 11: Dual-source 64-channel Electrocardiographic-gated Computed Tomography After Contrast Injection

Three-chamber diastolic image from a 60-year-old female with a malfunctioning mechanical mitral prosthesis. Anterior leaflet remains closed (arrow), while poster leaflet opens (arrowhead).

Figure 12: Dual-source 64-channel Electrocardiographic-gated Computed Tomography After Contrast Injection

Two-chamber image from a 54-year-old female with partial dehiscence of the posterior annuloplasty band (arrow). Normally positioned annuloplasty band in atrioventricular groove (arrowhead).
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Surgical Treatment

Definitive treatment for mitral valve repair disease requires surgical intervention, and in most cases repair is favored instead of mitral replacement.11 In patients with suspected complications from mitral valve surgery, CT is preferred over MRI because of its superior spatial resolution and decreased susceptibility to metallic artifact.12 Cine CT has non-specific imaging features.13 The most common neoplasm of the mitral valve is papillary fibroelastoma, a small benign tumor usually located on the atrial side of the valve away from the leaflet free edge.14 Rarely, myxoma, lymphoma, sarcoma, or metastasis can involve the mitral apparatus.15

Conclusion

MRI and CT are important adjunctive tools in the evaluation of mitral pathology. These two modalities not only identify many of the causes of mitral disease, but can also quantify the severity of valvular dysfunction. In addition, CT is particularly useful in identifying complications in patients following mitral valve surgery. Currently, MRI and CT assessment of the mitral valve is limited to patients with known mitral disease. As the use of cardiac MRI and CT grows, awareness of the imaging appearance of the normal mitral valve and its various diseases may foster recognition of unsuspected mitral pathology in patients being imaged for other purposes.

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