Evaluation of Cardiac Valves Using Multidetector CT

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KEYWORDS

• Computed tomography • Valves • Multidetector
• Aortic • Mitral

Recent technological advances in multidetector computed tomography (MDCT) scanners have allowed lower radiation dose and higher spatial and temporal resolutions, making fast heart rates and arrhythmias less of a limiting factor. This improvement has increased the number of potential applications of cardiac CT, although most patients still are referred for coronary CT angiography (CTA). During a routine CT of the heart, all four cardiac valves are imaged and may be visualized. Valvular calcification, particularly of left heart valves, is a frequent incidental finding on chest and cardiac CT scans and can be seen in up to 30% of patients.[1–3] In addition to the detection of valvular calcium, ECG gating has enabled the evaluation of leaflet morphology and function during a contrast-enhanced CTA, even in the absence of calcification.

The frequent identification of valve calcium on CT illustrates the prevalence of valvular heart disease (VHD), which affects 2.5% of all adults in the United States. The left-sided valves are involved more frequently, and mitral regurgitation (MR) is the leading cause of VHD.[4] In general, the initial clinical sign observed in VHD is a murmur during a physical examination. Occasionally, the first indication of VHD is the presence of symptoms from cardiac remodeling and/or hemodynamic compromise. The initial and preferred diagnostic test is Doppler transthoracic echocardiography.[5] Its high resolution, excellent safety profile, and visualization of both valvular anatomy and blood flow makes echocardiography the current cornerstone of VHD evaluation. Cardiac catheterization, long regarded as the reference test for the hemodynamic significance of valvular abnormalities, is performed less commonly now, although it still may be needed when the results of noninvasive tests are inconclusive. Moreover, invasive coronary angiography (CA) frequently is necessary to rule out significant coronary artery disease (CAD) preoperatively if surgical correction is indicated. Cardiac magnetic resonance has emerged as the most robust noninvasive alternative to echocardiography for VHD evaluation. Magnetic resonance usually is reserved for patients who have poor acoustic windows, inconclusive noninvasive results, discrepancies between echocardiography and catheterization, or a mismatch between diagnostic testing and symptoms. Cardiac CT for VHD assessment might be considered under the same circumstances, although CT has the disadvantages of depicting anatomy but not flow and of requiring ionizing radiation and nephrotoxic contrast agents. Therefore, it is unlikely that a cardiac CT will be performed exclusively for valvular evaluation unless the echocardiography is insufficient and there are contraindications for magnetic resonance (ie, the presence of a defibrillator). Useful information regarding valvular status or even calcium scoring can be obtained during a conventional coronary CTA, however. Moreover, growing evidence supports the use of coronary CTA to rule out significant CAD before valvular surgery in selected patients. This article reviews the most common CT findings associated with VHD and discusses technical aspects for optimal valvular assessment.

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PERFORMING A CARDIAC CT IN A PATIENT WHO HAS VALVULAR DISEASE

Protocol Optimization

As mentioned earlier, CAD assessment usually is the primary indication for cardiac CT in patients who have known VHD. Thus, imaging protocols usually are tailored to the evaluation of the coronary arteries. Before the contrast-enhanced CTA, a non-contrast CT often is acquired for the assessment of coronary calcium. These images also can be used to detect valvular calcification. Because of the lower radiation dose associated with prospective ECG gating, this approach usually is recommended for coronary calcium scoring.[6] Images typically are obtained at mid-diastole, when there is less coronary motion. This phase of the cardiac cycle also results in the lowest variability when quantifying aortic valvular calcium.[7] As reviewed later, determination of the degree of aortic valve calcification may provide important information with respect to valvular status and prognosis.

In contrast-enhanced coronary CTA, the use of the thinnest collimation available in the scanner is recommended for optimal visualization of the usually thin valve leaflets. Retrospective gating has been the most commonly used technique for ECG synchronization during coronary CTA. It also allows visualization of the heart in cine loops, which makes examination of biventricular function and valvular motion possible. Prospective ECG gating offers the distinct advantage of lower radiation exposure; however, it may be detrimental for the assessment of valvular pathology, because only valvular anatomy, but not motion, can be studied. Thus, if valvular evaluation is intended, retrospective ECG gating remains the technique of choice. Both the thinner collimation and retrospective gating capabilities are advantages of MDCT over electron beam CT, although the latter possesses superior temporal resolution and results in lower radiation exposure. When retrospective gating is used, implementation of ECG-based tube current modulation, commonly with maximal output during diastole and lower output during systole, leads to significant reductions in radiation dose.[8] This technique, however, also result can in suboptimal evaluation of stenotic lesions of the semilunar valves and of regurgitant lesions of the atrioventricular valves. Maximal output may be programmed to occur during systole if these abnormalities are suspected and if coronary evaluation is not hampered (ie, in patients who have faster heart rates). Alternatively, tube modulation may need to be avoided for optimal valvular evaluation.

In contrast administration, the standard use of a saline chaser bolus may limit visualization of right heart valves during coronary CTA. Therefore, optimized protocols that provide some degree of enhancement of the right cardiac chambers are preferred if these valves are to be studied. These methods include biphasic protocols that combine an infusion of contrast followed by a mixture of contrast and saline or contrast infusion at two different rates followed by saline and triphasic protocols that combine an infusion of contrast, followed by a mixture of contrast and saline, followed by saline.

Data Analysis

With the aid of specialized computer software, the amount of calcium in the coronary arteries and in the cardiac valves can be quantified accurately. The Agatston score is the quantification method most commonly used in clinical practice, although the volume and mass methods have been proposed because of their superior reproducibility.[7] In ex vivo comparisons with the true calcium content of explanted valves, the amount of calcification is quantified precisely with electron beam CT.[9]

Valvular abnormalities also can be seen by playing a cine movie of multiphasic contrast-enhanced CTA reconstructions and analyzing the leaflet motion throughout the cardiac cycle. The leaflets of stenotic valves often are thickened, calcified, and display reduced opening (in diastole for atrioventricular valves and in systole for semilunar valves). Evaluation of regurgitant valves also may reveal structural abnormalities such as leaflet prolapse or incomplete coaptation. Stenosis severity usually is measured by finding the cardiac phase with the largest opening of the stenotic valve and using the method of valvular area planimetry. The inner contour of the valve opening is traced manually at the level of the leaflet tips and in a plane parallel to the annulus as determined from two orthogonal double-oblique views (**Fig. 1**). The same approach can be applied to the area of inadequate leaflet coaptation in regurgitant lesions, to quantify the regurgitant orifice. From the cine images, biventricular end-diastolic, end-systolic, and stroke volumes, ejection fractions, and myocardial mass also can be measured precisely.[10,11] These parameters are known to portend vital prognostic and therapeutic implications in patients who have VHD.[5] In isolated regurgitant lesions, the regurgitant volume also can be derived from the difference between the left and right ventricular stroke volumes.[12]