Computed Tomography Evaluation in Valvular Heart Disease

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Abstract

Valvular heart disease commonly affects patients evaluated in the cardiology practice. Although Echocardiography is the primary modality for the evaluation of patients with suspected or known valvular heart disease, cardiac CT has distinct advantage in the evaluation of several anatomical features of the cardiac valves, including the extent of calcification, the geometry of the annulus and the evaluation of biological and mechanical prostheses. It is important for cardiologists, radiologists and other cardiac imaging specialists to recognize the features of normal and abnormal valves in patients who are referred for cardiac CT evaluation.

Keywords

Cardiac valve • Aortic stenosis • Aortic regurgitation • Mitral Stenosis • Mitral Regurgitation • Bioprosthetic valves • Mechanical prosthetic valves • Trans-aortic valve replacement (TAVR)

Introduction

Valvular heart disease (VHD) affects 2.5 % of U.S. adults and predominantly involves the left cardiac chambers. Regurgitant lesions are more common than stenotic, and mitral regurgitation (MR) is the most prevalent abnormality [1]. Doppler echocardiography is the initial imaging modality of choice, allowing for comprehensive diagnosis in the majority of patients [2, 3]. In cases of poor acoustic window and/or disparate results regarding disease severity, additional tests may be required. Cardiac catheterization is a time-honored modality, but is limited by its invasive nature. Magnetic resonance imaging (MRI) has become an excellent noninvasive alternative for both valvular insufficiency and stenosis [4]. Due to the need for radiation and contrast, computed tomography (CT) has a limited role for the evaluation of VHD as the primary indication. It may occasionally be employed as such when echocardiographic results are inconclusive and the patient is not a good candidate for MRI. Table 14.1 outlines the strengths and weaknesses of the different imaging modalities used to assess VHD [5]. CT is increasingly being used for preoperative evaluations for noninvasive coronary angiography and for workup for transcatheter heart valve replacement. Useful information on valve anatomy and function can simultaneously be obtained from a coronary CT examination.

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Table 14.1 Strengths and weaknesses of the different imaging modalities used to assess VHD

Parameter	Transthoracic echocardiography	Transesophageal echocardiography	Cardiac CT	Cardiac MRI
Spatial resolution	Very good. Pixel size 1–2 mm.	Excellent. Pixel sizes 0.5–1.0 mm.	Excellent. Pixel sizes 0.6–0.75 mm	Good. In plane resolution is good, but through-plane resolution is fair, 6–8 mm.
Temporal resolution	Excellent. 30–60 frames/s in real time.	Excellent. 30–60 frames/s in real time.	Dependent on scanner technology. 10–20 frames per beat if ECG gating applied.	Depends on pulse sequence and heart rate. 20–30 frames per beat if ECG gating applied.
Flow velocity and volume measurements	Excellent with Doppler ultrasound.	Excellent with Doppler ultrasound.	Poor. No current validated clinical method for measuring flow velocity or flow volume at CT.	Good with cine phase-contrast imaging. Not as widely used or standardized as Doppler measurements.
Patient specific limitations	Poor acoustic windows in some patients.	Invasive and requires sedation.	Images are easily acquired in many patients, but uses radiation and contrast material, which limits use.	Requires compliant patient. Claustrophobia limits uses. Cannot be used with pacemakers or defibrillators.
Ancillary information	Good. Cardiac dimensions can be measured, although with less precision than with CT or MRI.	Good. Cardiac dimensions can be measured, although with less precision than with CT or MRI.	Excellent. Quantitatively measures left ventricular dimensions and volumes.	Superior.

General Considerations

A diagram summarizing the potential applications of CT for the evaluation of patients with VHD is shown in Fig. 14.1. The Society for Computed Cardiac Tomography recently released consensus guidelines for the appropriate use of cardiac CT to evaluate non-coronary structures including cardiac valves. It is appropriate to use cardiac CT to evaluate native and prosthetic valves with suspected clinically significant valvular dysfunction if the images from other noninvasive methods are inadequate. It is not recommended as the initial imaging modality to assess valvular anatomy and function [6].

Valvular assessment includes the detection of calcification on non-contrast scans and of other aspects of valvular anatomy and cardiac function using contrast enhancement. Quantification of valve calcification follows the same principles as coronary calcium scoring, and the "Agatston", volumetric and mass scores have been proposed. Regarding contrast-enhanced CT, detailed evaluation of valvular function and anatomy is possible for both regurgitant and, particularly, stenotic lesions through planimetry of the valve area.

CT also allows for accurate quantification of ventricular volumes, ejection fraction and mass [7], all of which carry important prognostic and therapeutic implications in patients with VHD. In isolated regurgitant lesions, the regurgitant volume and regurgitant fraction can be derived from the difference between the left and right stroke volumes [8]. Stenosis or regurgitation of the atrioventricular valves usually results in atrial enlargement. Significant regurgitation of any valve eventually causes ipsilateral ventricular dilatation, often accompanied by eccentric hypertrophy. Stenotic lesions of the semilunar (aortic and pulmonary) valves lead to concentric hypertrophy and later may also lead to ventricular dilatation. Post-stenotic dilatation of the pulmonary trunk or the ascending aorta may be present as well.

CT can provide important information regarding hemodynamic repercussions of valvular lesions. Enlargement of the right heart chambers can be caused by tricuspid/pulmonary abnormalities or secondary pulmonary hypertension, and typically leads to posterior rotation of the cardiac axis (Fig. 14.2). Pulmonary vein dilatation and interstitial and alveolar lung edema are all signs of increased left atrial pressures and left-sided heart failure. Similarly, dilatation of the pulmonary arteries, right heart chambers, superior and inferior vena cava, pleuro-pericardial effusions and ascites, are suggestive of pulmonary hypertension and/or right ventricular heart failure [9].

Cardiac CT has had a major emergence in the realm of preoperative assessment of transcatheter aortic valve replacement (TAVR). It is crucial in the assessment of annular area (Fig. 14.3), diameter, valve leaflet morphology/calcification (Fig. 14.4), optimum deployment angles, and peripheral vascular assessment (Figs. 14.5 and 14.6). The severity of the aortic valve Agatston calcium score, calculated by cardiac CT, has been shown to correlate with degree of paravalvular leak following transcatheter heart valve implantation.

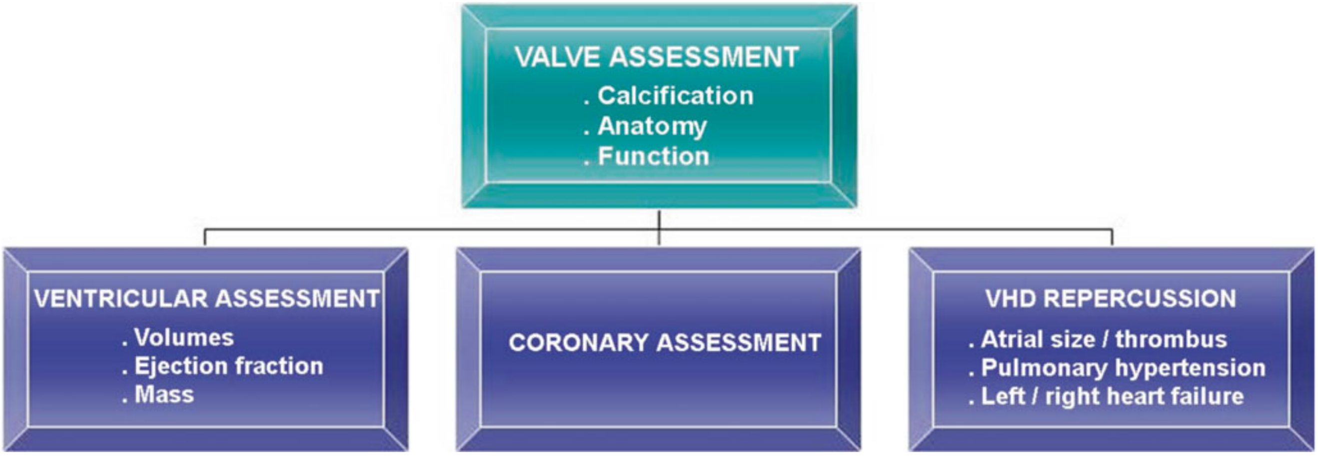

Fig. 14.1 Comprehensive evaluation of valvular heart disease (*VHD*) with CT

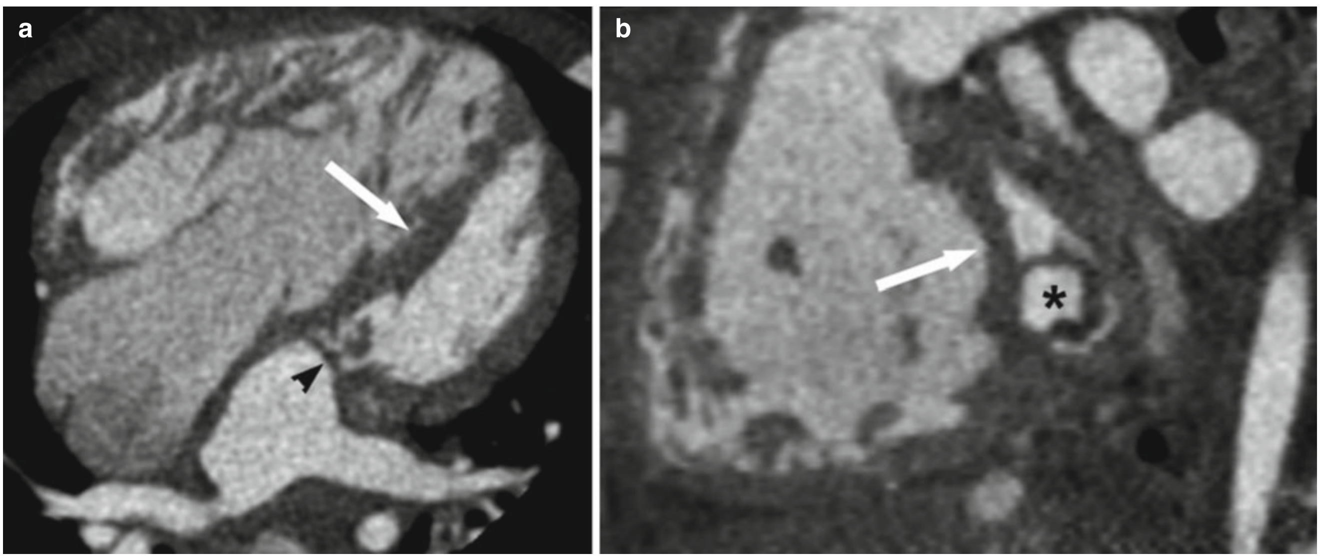

Fig. 14.2 Four chamber (panel **a**) and short-axis (panel **b**) views of a contrast-enhanced CT scan in an young patient with congenital mitral stenosis ("parachute mitral valve"; *arrowhead* and *asterisk*) and secondary pulmonary hypertension. There is severe right ventricular hypertrophy and enlargement, together with abnormal interventricular septal bowing indicative of right ventricular pressure/volume overload (*arrows*)

CT coronary angiography for preoperative evaluation in VHD is also increasingly being used. A high accuracy for the detection of significant coronary stenoses has been reported, with slightly lower diagnostic yield in cases of aortic stenosis (AS) due to frequent aortic and coronary calcifications [10–13]. These studies have demonstrated high negative and moderate positive predictive value; thus, patients referred for valvular surgery without significant coronary stenoses by CT may safely avoid the need for invasive angiography [14]. On the other hand, patients with greater than a mild degree of luminal stenosis or extensive calcifications need to have a confirmatory catheterization. For this reason, it seems prudent to consider CT for this application only in selected patients with low or intermediate pre-test probability.

A typical imaging protocol is summarized in Table 14.2. Contrast infusion is routinely followed by saline, resulting in a more compact bolus and easier evaluation of the right coronary artery; however, it may also impair the visualization of right chambers and valves. This can be overcome by employing dual- or triple-phase injection protocols [15, 16]. Retrospective ECG gating is advantageous in patients with VHD at the expense of higher radiation dose. ECG-based tube current modulation can be used, but it may limit the assessment of both ventricles and valves, particularly in obese patients and in the cardiac phases with lower output. If such evaluation is intended, it may be necessary to avoid its use.

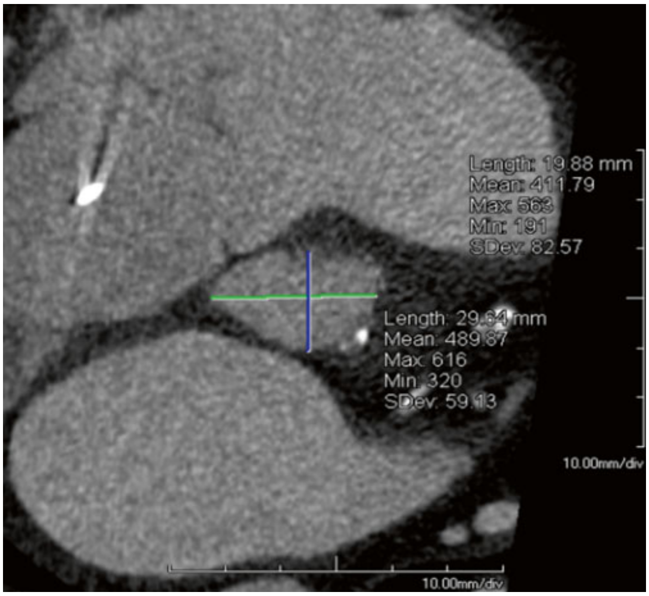

Fig. 14.3 Axial-oblique image of the aortic annulus in a patient evaluated for trans-aortic valve replacement (TAVR) demonstrating an elliptical geometry. *Green* is antero-posterior and *blue* is transverse diameter of the LV outflow tract

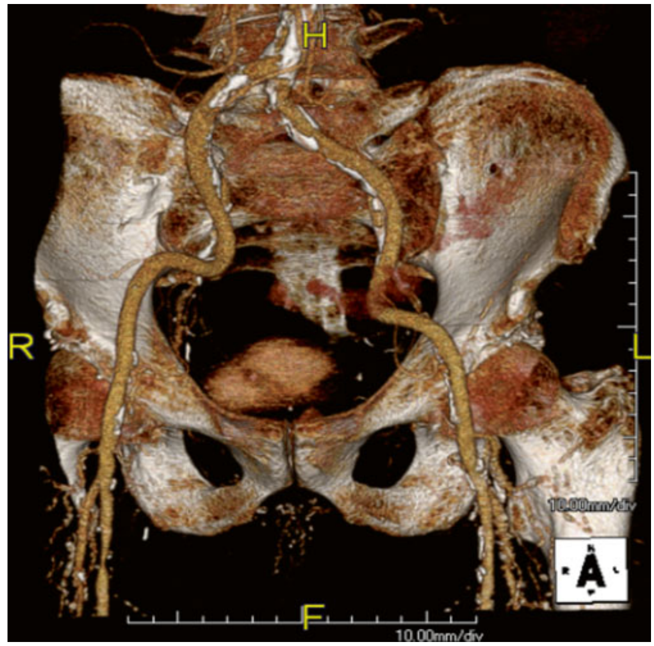

Fig. 14.5 3-D Volume-rendered image of the iliac and femoral arteries in a patient evaluated for trans-aortic valve replacement (TAVR) demonstrating moderate calcification and tortuosity

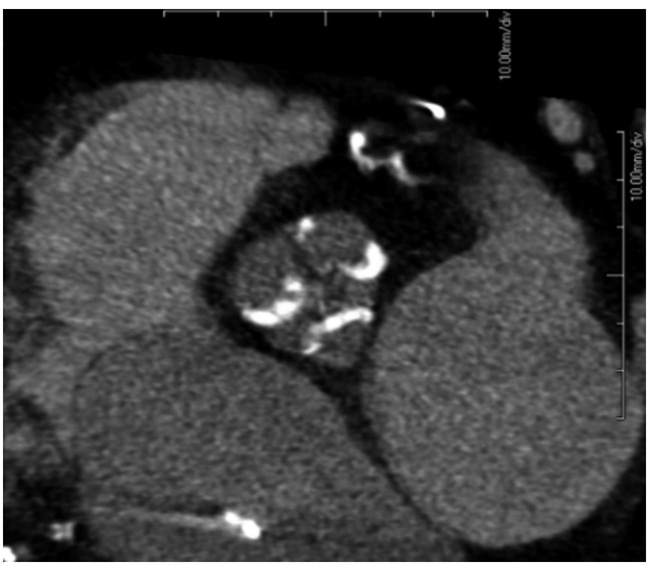

Fig. 14.4 Axial-oblique image of the aortic valve in a patient evaluated for trans-aortic valve replacement (TAVR) demonstrating moderate leaflet calcification

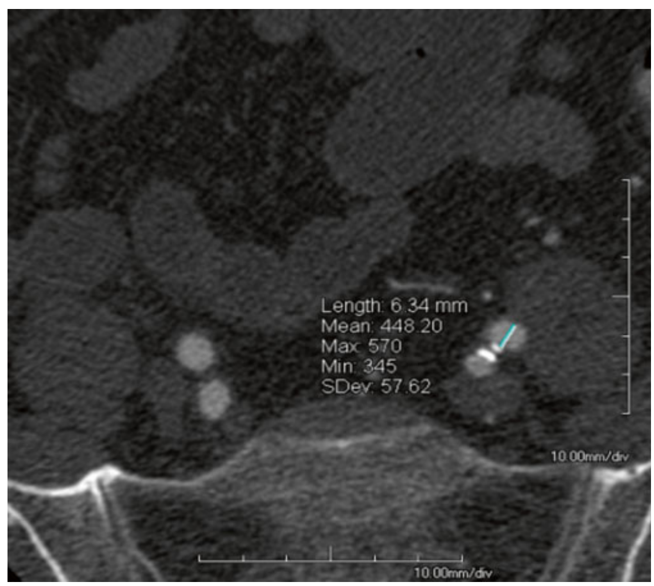

Fig. 14.6 Axial image of the proximal femoral arteries in a patient evaluated for trans-aortic valve replacement (TAVR)

Specific Valvular Abnormalities

Aortic Stenosis

Aortic stenosis (AS) is often accompanied by cusp calcification and tends to occur in patients with trileaflet valves above 65 years of age or in younger patients with congenital abnormalities (i.e. bicuspid valves). Severe calcification associated with faster rates of stenosis progression and increased cardiac event rates [17]. Aortic valve calcification can be accurately quantified using CT (Fig. 14.7), and interscan reproducibility is >90 % [18–20]. The amount of calcification is directly correlated with the severity of AS [19–22], although the relationship is curvilinear with stenosis severity increasing more rapidly at lower than higher calcium loads.

Table 14.2 Imaging protocol

Scanning protocol (for a 256-slice scanner)	
Tube voltage (kV)	100–120
Tube output (mA)	500–800
Detector number	128
Detector collimation (mm) ECG gating	0.6 Retrospective/Prospective
Helical pitch[a]	0.16–0.18
Rotation time (ms)	270–330
Tube current modulation[a]	
(HR ≤ 65) (HR > 65)	On Off
Contrast protocol (370 mgI/cc)	
Contrast amount (cc)	80–100
Contrast infusion rate (cc/s)	4–5
Saline amount (cc)	50
Saline infusion rate (cc/s)	4–5
Image reconstruction	
Reconstruction filter	Intermediate
Slice width (mm)	0.6
Increment (mm)	0.3 mm
Matrix	512 × 512
Reconstruction interval	Every 5–10 %
Image analysis: Axial images, MPR, MIP (cine loops and still frames)	

Typical scanning protocol for MDCT coronary angiography employed in our institution
ECG electrocardiogram, *HR* heart rate, *MPR*: multiplanar reformation, *MIP* maximum intensity projection
[a]If retrospective gating

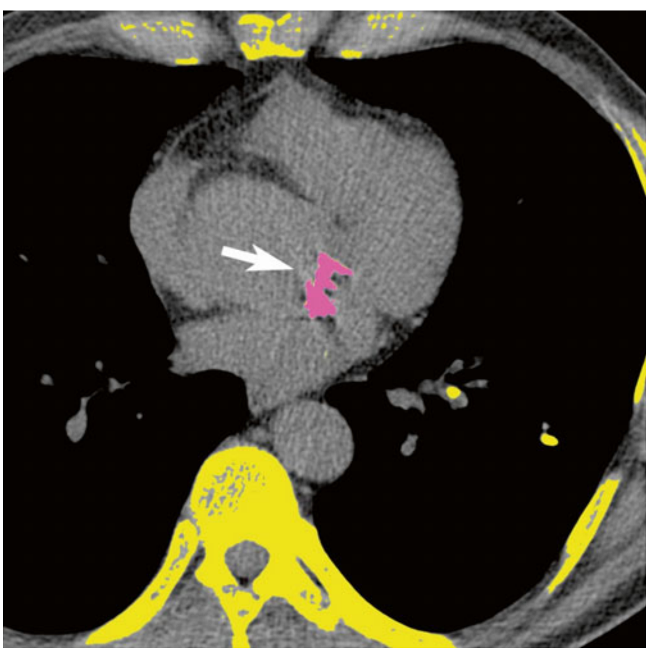

Fig. 14.7 Axial, non-contrast CT image in a patient with moderate aortic stenosis, demonstrating the quantification of aortic valve calcium (*arrow*) using the same approach as for coronary calcium scoring. The valvular calcium score ("Agatston") was 2227

The incremental value of the information derived from the aortic valve calcium score may be particularly useful in patients with low cardiac output and reduced transvalvular gradients.

Contrast-enhanced CT can precisely evaluate valve morphology, accurately differentiating trileaflet from bicuspid valves (Fig. 14.8a, b). Planimetric determinations of the aortic valve area (Fig. 14.8c) have shown excellent correlation with echocardiographic and invasive measurements [23–29].

CT has emerged as the integral imaging modality for transcatheter heart valve replacement. As opposed to conventional aortic valve replacement, direct visualization of the valve and annulus is lacking during the TAVR procedure. As a result, imaging is necessary to allow for appropriate valve sizing. CT is used to assess valve morphology, location and degree of calcification, annular sizing, optimum deployment angles, and for presence of peripheral vascular disease. These assessments play a role in predicting success of valve implantation and risk of paravalvular leak in these patients.

Expert consensus documents have been released on the use of CT before TAVR stating that CT should be used in the

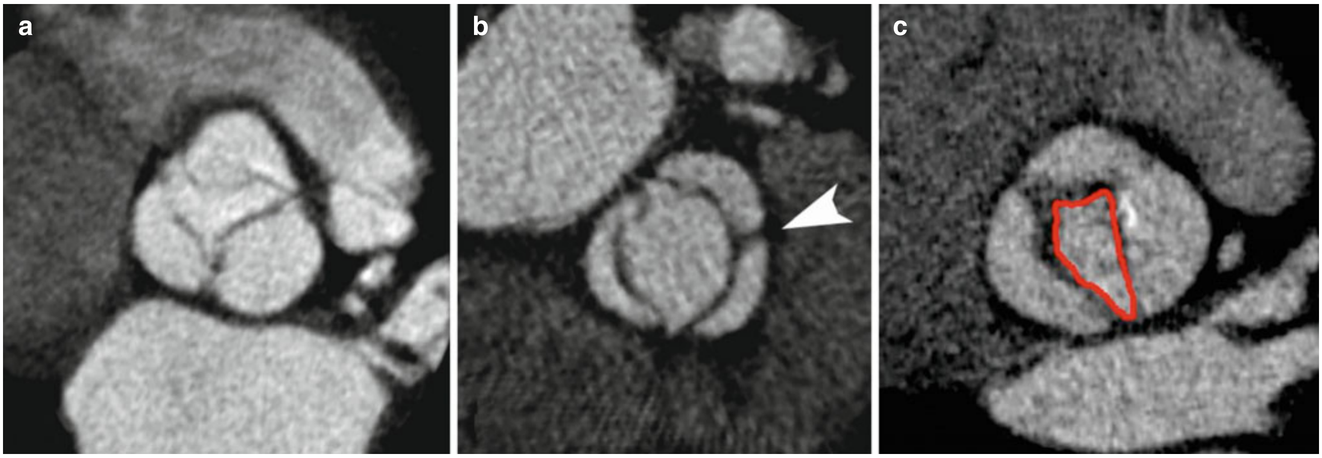

Fig. 14.8 Double oblique systolic reconstructions of contrast-enhanced CT scans showing a tri-leaflet (panel **a**) and a bicuspid aortic valve (the *arrowhead* indicates the fusion of the right and left coronary sinuses; panel **b**). Planimetry of the valve can be performed subsequently (red contour, panel **c**): the figure shows a bicuspid aortic valve with moderate stenosis (valve area = 1.2 cm^2)

assessment of all patients being considered for TAVR unless contraindicated and that datasets should be interpreted jointly within a multidisciplinary team [30].

Aortic Regurgitation

CT may be useful in evaluating the mechanism leading to aortic regurgitation (AR). AR caused by degenerative valve disease is characterized by thickened and/or calcified leaflets, and the area of lack of coaptation may be visualized in diastolic phase reconstructions centrally or at the commissures. In cases of AR secondary to enlargement of the aortic root, the regurgitant orifice is typically located centrally (Fig. 14.9). Other etiologies that can be depicted include interposition of an intimal flap in cases of dissection, valve distortion or perforation in cases of endocarditis, or leaflet prolapse observed in dissection and in Marfan syndrome. Regurgitant orifice areas measured by planimetry using MDCT correlate well with echocardiographic parameters of AR severity, such as the vena contracta width and the ratio of regurgitant jet to left ventricular outflow tract height, and allow for the detection of moderate and severe AR with high accuracy [31–33].

Mitral Stenosis

As in the case of aortic valve calcification, the presence of calcium in the mitral annulus is associated with systemic atherosclerosis and carries negative prognostic implications. The amount of mitral annular calcium can also be quantified with CT (Fig. 14.10), although reproducibility appears to be somewhat lower [18]. In rheumatic mitral stenosis (MS), calcification can extend to the leaflets, commissures, sub-valvular apparatus or even the left atrial wall. MS is often accompanied by marked atrial enlargement involving the appendage. The presence or absence of thrombus in the left atrial appendage can be determined after contrast administration with very high sensitivity although lower specificity since slow flow may impair opacification, which may be increased by adding delayed imaging [34, 35]. Planimetry of mitral valve opening by CT provides accurate assessment of MS severity (Fig. 14.11) [36].

Mitral Regurgitation

Both echocardiography and cardiac CT have high sensitivities (92.3 % and 84.6 %, respectively) and specificities (100 % each) for assessing mitral valve abnormalities compared with intraoperative findings, and echocardiography is more sensitive than CT for depicting each prolapsed leaflet of the mitral valve [37]. Echocardiography has been considered the reference imaging modality for mitral valve evaluation given the radiation dose exposure and inferior temporal resolution of CT. In mitral valve prolapse, for example, the use of echocardiography alone to identify the exact site of prolapse is clinician dependent and sometimes difficult, even for those with expertise, because of the limited acoustic window and the complex structure of the mitral apparatus.

In patients with mitral valve prolapse, CT can demonstrate the presence of leaflet thickening or the degree and location of prolapse (Fig. 14.12 and Video 14.1). In cases of MR secondary to annular enlargement, often accompanying dilated cardiomyopathy, dimensions of the annulus can be accurately quantified, and a central area of insufficient leaflet coaptation may be observed. Although quantifying MR degree may be difficult, preliminary data suggests that

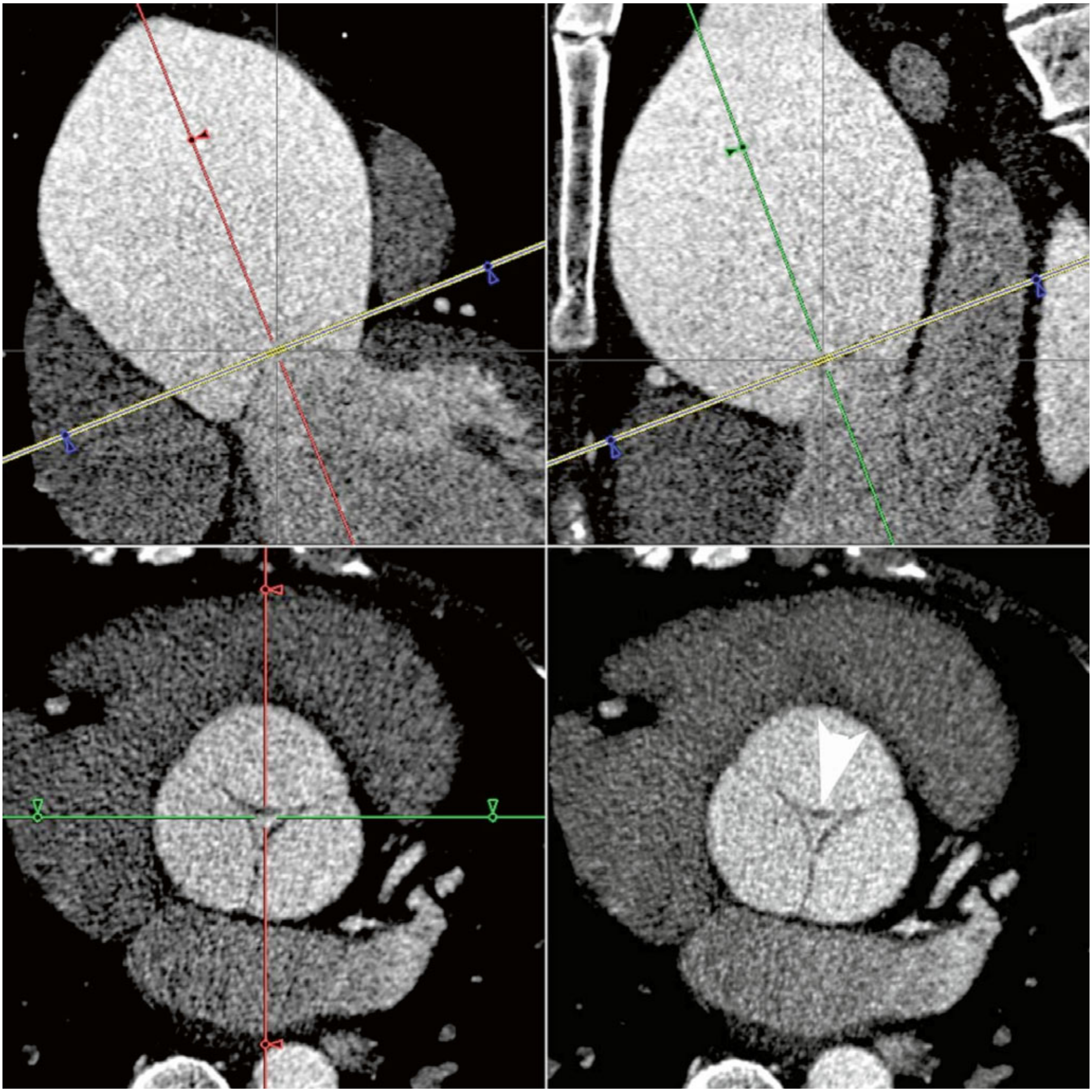

Fig. 14.9 Contrast-enhanced MDCT in a patient with an aneurysmal aorta and aortic insufficiency. The valvular plane (*yellow line*; *left lower panel*) is oriented perpendicular to two orthogonal planes aligned with the ascending aorta (*red and green lines*). A large, central area of insufficient leaflet coaptation during diastole (*right lower panel*; *arrowhead*) can be visualized

planimetry of the regurgitant orifice by CT correlates well with echocardiographic grading of severity [38].

Pulmonic Valve Disease

Pathology of the pulmonic valve, whether from idiopathic causes, infective endocarditis, thrombus, regurgitation/stenosis, or secondary to congenital heart disease is difficult to evaluate by echocardiography in the adult patient. Therefore, CT and MRI, due to their good spatiotemporal resolution, large field of view, and multiplanar reconstruction techniques, are playing increasingly important roles in the evaluation of this valve.

For visualizing the pulmonary valve, the CT intravenous contrast medium injection protocol should be optimized to ensure that there is adequate contrast opacification in the right cardiac chambers. For morphological evaluation of the valve, prospective electrocardiography (ECG) triggered acquisition should be used to minimize radiation dose. However, if functional analysis of the valve or the RV is desired, retrospective ECG-gated multi-phasic acquisition with tube current modulation is the ideal scanning mode [39].

Infective Endocarditis

Studies have shown that cardiac-gated CTA has excellent sensitivity, specificity, and positive predictive and negative predictive values in the preoperative evaluation for suspected infective endocarditis, in addition to excellent correlations with preoperative TEE and intraoperative findings [40].

Fig. 14.10 Short-axis view at the level of the mitral valve, showing extensive annular calcification (*arrows*)

Vegetations are often mobile and tend to be on the atrial aspect of atrioventricular valves, and on the ventricular aspect of semilunar valves (Fig. 14.13). CT can be particularly useful in the demonstration of perivalvular abscesses as fluid-filled collections (Fig. 14.14) that may retain contrast in delayed imaging [41]. In a recent study, MDCT correctly identified 26 out of 27 (96 %) patients with valvular vegetations and 9 out of 9 (100 %) patients with abscesses, which were better characterized by MDCT than with trans-esophageal echocardiography [42]. Intravascular contrast administration should be optimized, and intravascular attenuation can be further accentuated by the use of 100-kV scan protocols whenever possible. Although the maximal temporal resolution of a scanner cannot be altered, the reconstruction frame of the dataset can and should be optimized when assessing valvular function. Reconstruction of 20- or 25-phase datasets (at 5 % or 4 % increments of the R-R interval) provides improved temporal depiction of valve motion that facilitates cine evaluation of valvular pathology, such as hypermobile vegetations. In addition, advanced image processing techniques, such as blood pool inversion (BPI) volume-rendering, can be used to allow 3-Dimensional/4-Dimensional (3-D/4-D) assessment of valvular structure and function [43]. In patients with aortic valve endocarditis with highly mobile vegetations, CT may be especially attractive as an alternative to invasive coronary angiography for preoperative evaluation.

Prosthetic Valves

Many of the aforementioned features of native VHD apply also to the evaluation of cardiac bioprostheses. Transthoracic echocardiography is useful for prosthetic valve evaluation, but can be limited by acoustic shadowing and poor acoustic windowing. Recently, cardiac CT has been recognized as a viable alternative to evaluation of prosthetic valve complications

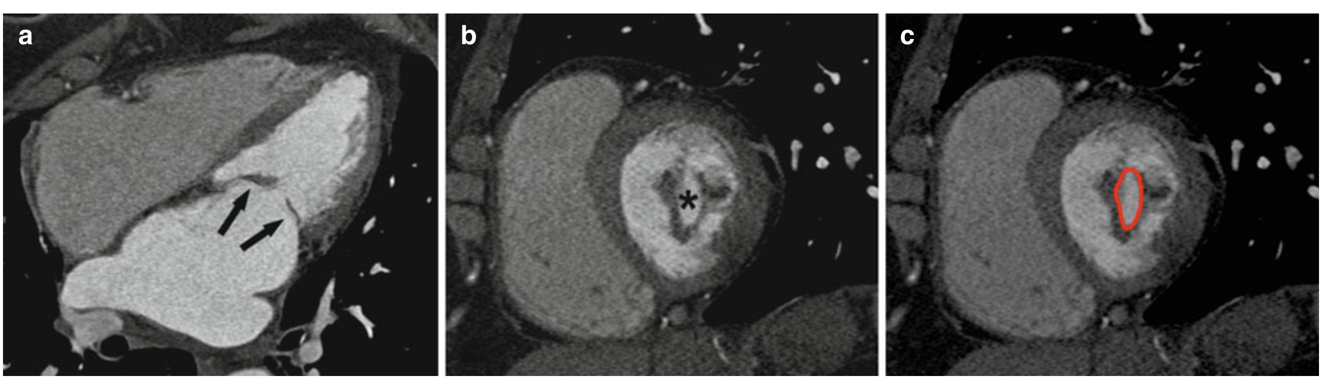

Fig. 14.11 Contrast-enhanced CT scan in the four-chamber and short-axis views (panels **a** and **b**, respectively) from a patient with rheumatic mitral stenosis. The typical thickening and restricted dome-shaped opening of the leaflets can be observed (*arrows* and *asterisk*). Planimetry of the valve (panel **c**) demonstrated moderate stenosis (*red contour*; area = 1.3 cm^2)

including valve thrombosis, dehiscence, pannus development, endocarditis, and paravalvular leak. However, careful attention to CT technique, achieving prescan target heart rates, extensive windowing adjustments, and awareness of normal postoperative paravalvular structures is imperative. Some valves, such as ball in cage valves, are not readily evaluable by CT because of extreme beam hardening artifact from the thicker metal struts found in these models. Whereas evaluation of most other valves using a very soft window with considerable windowing adjustments is to minimize beam hardening is certainly possible [44].

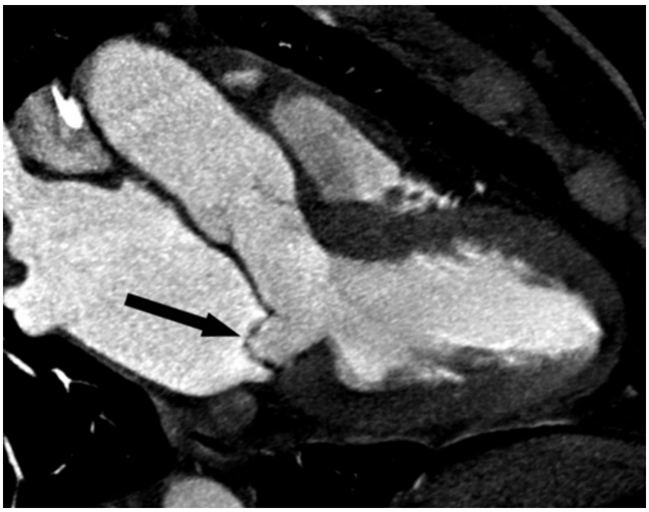

Fig. 14.12 End-systolic three-chamber view of the left ventricle demonstrating prolapse of the posterior mitral leaflet (*arrow*)

Recent work suggests iterative reconstructions may reduce beam-hardening artifact from prosthetic valves compared with filtered back projection reconstruction techniques [45]. Motion artifact can be adequately reduced by administration of beta-blockade to achieve heart rates between 50 and 60 bpm. Motion artifact is worst for aortic valve prosthesis during ventricular systole and for mitral valve prosthesis during end-diastole. Thus, it has been found that imaging in mid-diastole is the most ideal for prosthetic valve evaluation [46]. CT is particularly useful for the evaluation of some types of mechanical valves. In Prostheses with two discs should open symmetrically (Fig. 14.15 and Video 14.2). In those with a single disc, the angle of opening can also be measured [47]. Finally, heterografts and homografts can be evaluated completely, including the distal anastomosis and the patency of the coronary arteries if these were reimplanted.

Imaging Pearls

- Plan ahead; as this will allow for imaging protocol optimization if valvular evaluation will be attempted.
- If simultaneous assessment of the right heart structures is intended, the contrast protocol should be optimized. An initial bolus of 80–100 cc followed by a mixture of

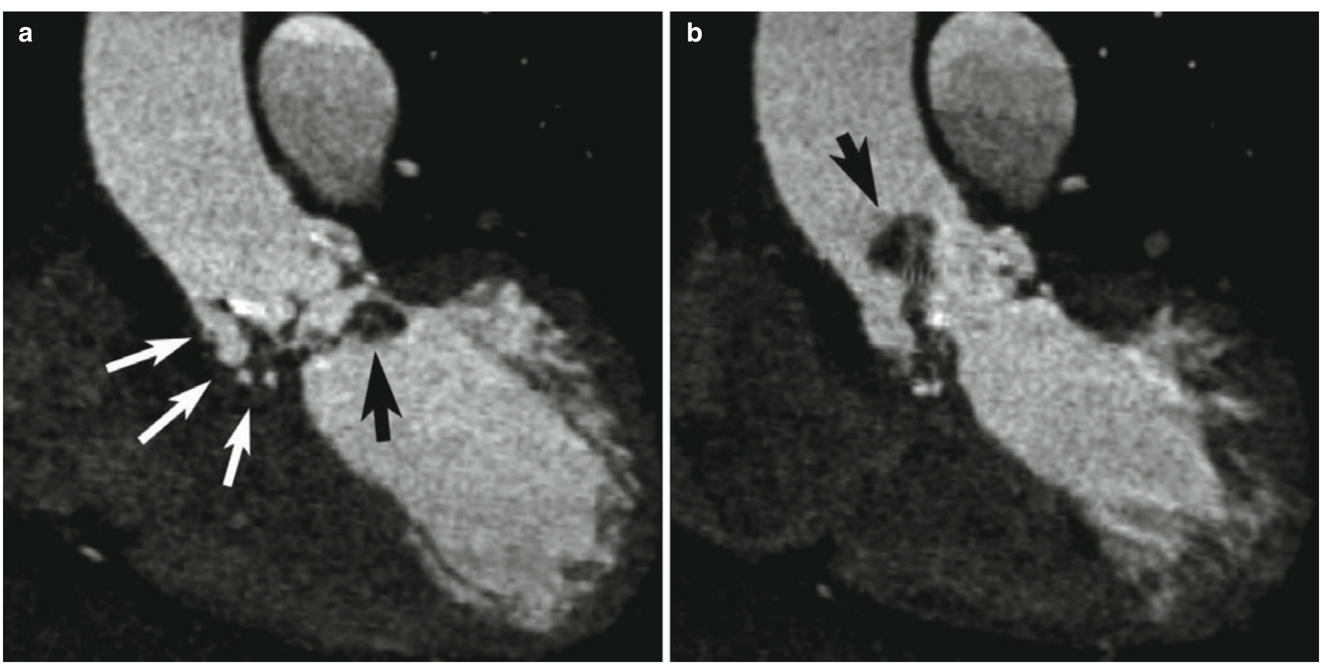

Fig. 14.13 Diastolic (panel **a**) and systolic (panel **b**) reconstructions of a contrast-enhanced MDCT study in a patient with a bioprosthesis in the aortic position. A large, mobile vegetation that prolapses into the ascending aorta in systole can be noted (*black arrows*). In addition, perivalvular thickening and fluid-filled collections can be noted (*white arrows*) indicating the presence of a perivalular abscess

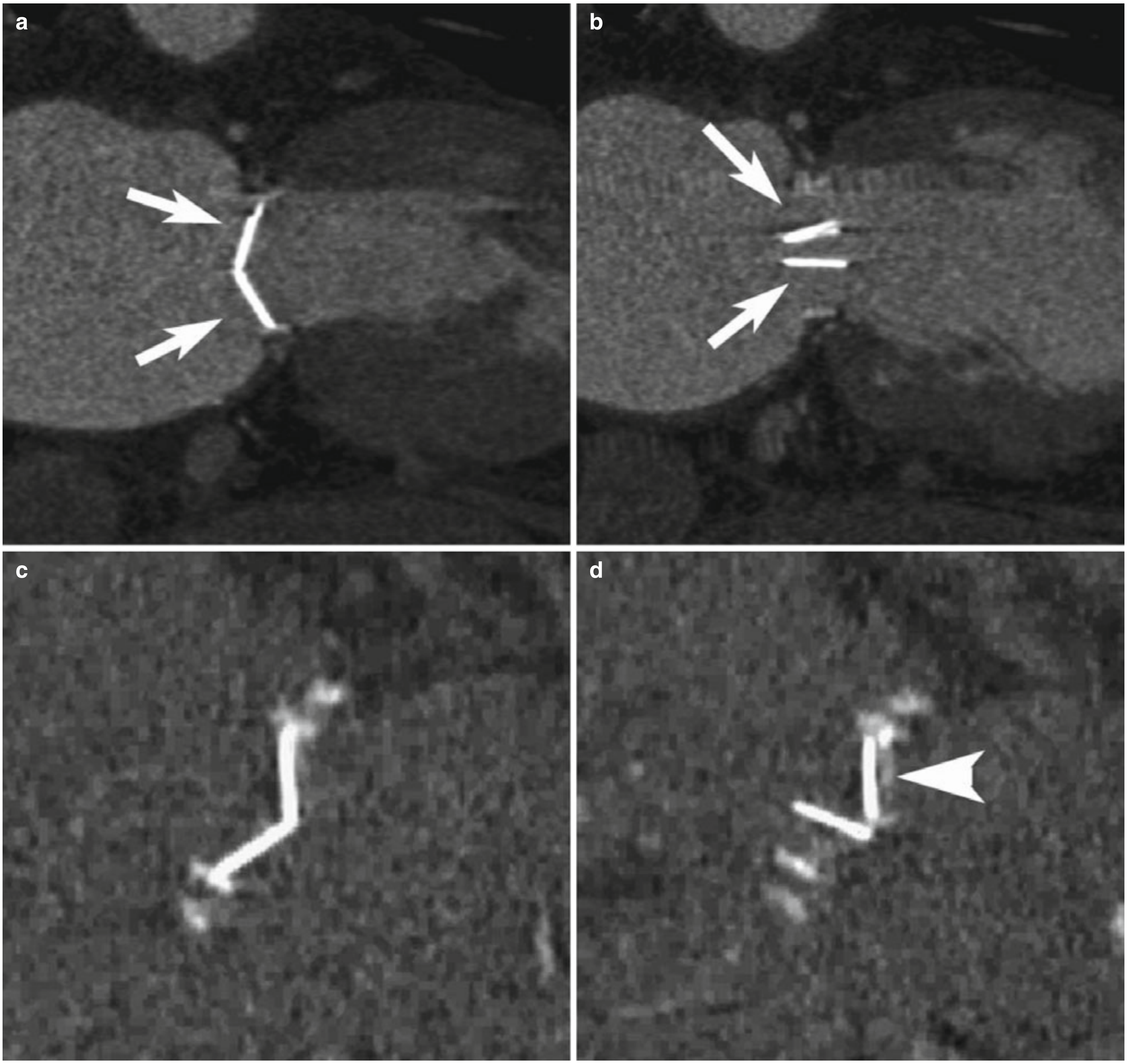

Fig. 14.14 Evaluation of mechanical prostheses by CT. The top row shows contrast-enhanced images (systole, panel **a**; diastole, panel **b**) of a normal-functioning mechanical prosthesis in the mitral position. The two discs close and open completely and symmetrically (*white arrows*) during the cardiac cycle. Comparable systolic (panel **c**) and diastolic (panel **d**) reconstructions of a non-contrast CT evaluation of a dysfunctional mitral prosthesis. One of the discs does not open in diastole (*white arrowhead*). Subsequent surgical intervention demonstrated prosthetic thrombosis

contrast and saline (1:1) at 4–5 cc/s will result in adequate coronary evaluation and sufficient right-heart opacification without excessive enhancement. Alternatively, a second infusion of contrast administered at a slower rate (2–3 cc/s) can be employed [15, 16].

- Quantification of ventricular end-systolic volumes and the degree of MR and AS requires adequate image quality during systole. It may be necessary to avoid tube current modulation in these cases. Alternatively, the maximal tube output can be timed to end-systole, which will provide adequate depiction of mitral closure and aortic opening, as well as potentially motionless coronary images, particularly at higher heart rates.
- If the entire thoracic aorta needs to be imaged (i.e. in cases of aneurysm with associated AR) and coronary evaluation is not required, using thicker detector collimation will enable reductions in radiation dose and breath-hold duration.

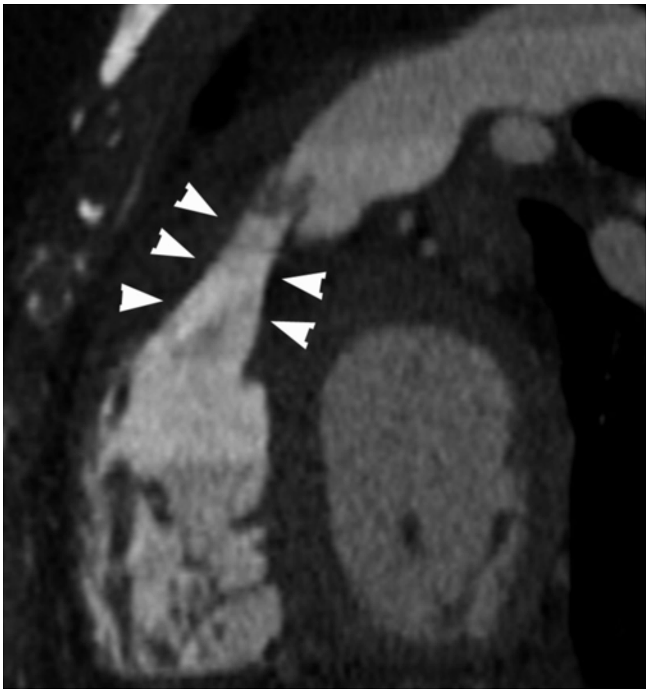

Fig. 14.15 Contrast-enhanced CT in a patient with pulmonary infundibular stenosis (*arrowheads*). The contrast protocol was optimized to provide adequate opacification of right heart chambers

- Most patients with VHD can tolerate beta-blockers for optimal coronary evaluation. However, caution and smaller doses are recommended in cases with severe degrees of left ventricular dysfunction/dilatation, AS, AR or pulmonary hypertension.
- Atrial fibrillation is common in patients with VHD. It may lead to a decrease in image quality and accuracy of valvular and ventricular assessment, although this is typically more significant for evaluation of the coronary arteries.
- For the evaluation of ventricular or valvular function with MDCT, reconstructions at every 10 % of the RR interval are usually sufficient. In specific cases, a more detailed evaluation of the valve can be obtained by reconstructing images at smaller intervals (i.e. every 5 %) in the cardiac phase of interest (for example, during systole for AS) [48].
- The combination of cine loops and still frames facilitates the detection of valvular abnormalities.
- CT imaging in the evaluation for TAVR should include imaging of the aortic root, aorta, and iliac, as well as common femoral arteries. To achieve the desired accuracy and to allow for adequate motion-free images, imaging of the aortic root must be synchronized to the electrocardiogram (ECG) either by retrospective ECG gating or by prospective ECG triggering, depending on patient characteristics. It is not necessary to image the entire aorta and iliofemoral arteries with ECG synchronization. For these sections, non-gated acquisitions will allow lower radiation exposure and faster volume coverage requiring lower contrast volumes. Since detailed dimensions of the aortic root and of the iliofemoral arteries must be obtained, spatial resolution must be high enough to provide adequate imaging. The optimal acquisition protocol is that which obtains a reconstructed slice width of <1.0 mm throughout the entire imaging volume.
- Variability of the quantification of aortic valve calcium is lowest in mid-diastole [49].
- A valvular "Agatston" score ≥1100 resulted in respective sensitivity and specificity of 93 and 82 % for the diagnosis of severe AS [20]. A score >3700 has a positive predictive value of near 100 % [25].
- The optimal plane to perform planimetry of the valvular area is parallel to the annulus as determined from two orthogonal double-oblique views perpendicular to the valve plane. The optimal level of that plane is the one showing the smallest area during the phase of maximum valve opening (Fig. 14.9).
- Quantification of the regurgitant volume/fraction from the difference in right and left stroke volumes is only accurate for isolated regurgitant lesions.
- A score evaluating leaflet mobility and thickening, subvalvular thickening and calcification, as well as the presence of left atrial thrombus, may determine whether MS can be treated percutaneously or surgically. CT can provide useful information for all of these features.
- The mitral valve is divided into the anterolateral commissure, posteromedial commissure, anterior leaflet and posterior leaflet. The leaflets are subdivided into three segments each (A1, A2 and A3; and P1, P2, and P3, from lateral to medial). Determination of which segments are affected and to what degree determines in part the likelihood of successful surgical repair in mitral valve prolapse.
- Sharper reconstruction filters and increasing window level of the image display facilitates evaluation of mechanical prosthetic valves.
- Optimum valve evaluation for both aortic and mitral prosthetic valves is best achieved during mid-diastole.

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