**Valvular Pathology Demonstrated on Cardiac CT**

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Learning objectives

To illustrate a spectrum of VHD as demonstrated on cardiac CT

To discuss the strengths and limitations of CT versus echocardiography and CMR in cardiac valve assessment

To discuss commonly encountered cardiac valve pathologies with accompanying cardiac CT images
Background

The prevalence of valvular heart disease (VHD) is increasing owing primarily to ageing populations with degenerative valvular disease (1). In recent years cardiac CT has become an increasingly valuable imaging modality in the assessment of VHD. Due to recent advances in CT technology, high quality images are obtained at lower radiation doses. Retrospective ECG gating enables visualisation of the valves throughout the cardiac cycle. Excellent demonstration of valve morphology is achieved with the use of multiplanar reformations. Direct planimetry allows accurate assessment of valve area - in patients with aortic stenosis for example, the smallest valve orifice area is identified in the axial plane during systole and measured with digital callipers (figure 2). If performed accurately, the measurements obtained correlate well with those obtained at transoesophageal echocardiography (6).

Whilst echocardiography remains the primary modality in cardiac valve imaging, cardiac CT is useful in patients who;

- are undergoing open cardiac valve surgery when simultaneous assessment of the coronary arteries is required

- are undergoing transcatheter valve implantation where simultaneous assessment of aortic annulus size, distance from coronary arteries to aortic annulus and vascular access routes is necessary.

- have prosthetic heart valves which have been suboptimally imaged on echocardiography due to image artefact.

- have infective endocarditis when assessment for subsequent complications is indicated, particularly in patients with prosthetic valves.

Cardiac CT has superior spatial resolution with shorter acquisition times in comparison to both echocardiography and CMR, however its temporal resolution is lower and there is an associated radiation dose to the patient. Tube current modulation and iterative reconstruction techniques are used to minimize radiation exposure (2).
Aortic stenosis

Aortic stenosis is defined as the obstruction of blood flow across the aortic valve due to narrowing of the valve opening area (figure 2). Common acquired causes include age-related degenerative valvular disease and rheumatic heart disease. The commonest congenital cause is a bicuspid aortic valve (figure 1). Based on echocardiographic standards the normal aortic valve opening area is 3-4 cm$^2$, mild stenosis: 1.5-3.0 cm$^2$, moderate stenosis: 1.0-1.5 cm$^2$ and severe stenosis: < 1.0 cm$^2$ (5). In patients with aortic stenosis, cardiac CT demonstrates varying degrees of valve thickening and calcification - the morphology of this can aid in determining the underlying aetiology. In age related disease, there is often extensive asymmetrical cusp calcification, which usually begins at the valve annulus. In rheumatic heart disease the typical pattern of disease is symmetrical cusp calcification progressing to cusp fusion with concomitant stenosis and regurgitation. Calcification of bicuspid valves is usually mild and confined to the commissures (4).

Aortic regurgitation

Aortic regurgitation is the backflow of blood across the aortic valve from the ascending aorta into the left ventricle during diastole due to incomplete valve closure (figures 3 and 4). Aetiologies can be broadly divided into diseases that affect the valve leaflets (rheumatic heart disease, infective endocarditis, bicuspid aortic valves) and those that dilate the aortic root (hypertension, ascending aortic aneurysm or dissection, collagen vascular diseases, syphilis). Cardiac CT demonstrates incomplete coaptation of valve leaflets during diastole and enables measurement of the regurgitant orifice area. Resultant left heart dilatation is seen in chronic disease.

Mitral stenosis

Mitral stenosis is relatively uncommon in developed countries. Rheumatic heart disease is the underlying aetiology in the overwhelming majority of cases. A characteristic "fish mouth" appearance to the valve leaflets may be seen on cardiac CT in the axial plane due to varying degrees of commissural fusion and calcification. Less common aetiologies include radiation exposure, connective tissue diseases and degenerative valvular calcification. Longstanding mitral stenosis results in elevated left atrial pressure, left atrial dilatation and pulmonary hypertension (7).

Mitral regurgitation
Mitral regurgitation occurs during the systolic phase of the cardiac cycle due to dysfunction of any component of the mitral valve apparatus. The clinical presentation may either be acute or chronic, both with differing underlying aetiologies. Causes of acute mitral regurgitation include infective endocarditis and chordae tendinae rupture (with resultant flail leaflet - figure 6). Chronic causes are numerous and include mitral valve prolapse (figure 6), elongation (or rupture) of the chordae tendinae and rheumatic heart disease (7). Echocardiography is used in the acute setting to determine the underlying cause of clinically apparent mitral regurgitation. Cardiac CT is commonly performed prior to surgical intervention, with visualisation of underlying aetiologies such as mitral valve prolapse, flail leaflets and cardiomyopathy.

**Tricuspid regurgitation**

Tricuspid regurgitation is commonly encountered in patients with right ventricular dilatation secondary to elevated pulmonary arterial pressure. There is subsequent dilatation of the tricuspid annulus and stretching of the leaflets, which fail to appose appropriately during systole (figure 12).

**Pulmonary stenosis**

Pulmonary stenosis is predominantly a congenital disorder (figure 9). Less commonly it can be due to acquired causes such as carcinoid heart disease. If congenital, it can be associated with anomalies such as Tetralogy of Fallot. Left untreated, the resultant elevated right ventricular pressure leads to right ventricular hypertrophy and dilatation. Post-stenotic enlargement of the main and left pulmonary arteries results from high velocity turbulent blood passing through the valve.

**Pulmonary regurgitation**

Pulmonary regurgitation is most commonly a sequela of disorders that dilate the pulmonary valve annulus such as pulmonary arterial hypertension and Marfan syndrome. Cardiac CT demonstrates incomplete apposition of valve leaflets at end diastole (figure 10). In chronic disease, right ventricular dilatation is evident due to volume overload.

**Prosthetic valves**

There are several types of prosthetic valves, which can be divided into mechanical prostheses and bioprostheses. Mechanical prostheses include: caged ball (Starr Edwards), bileaflet (St Jude - figure 13) and tilting disc valves. Bioprosthetic valves are
bovine or porcine in origin. Cardiac CT provides excellent visualisation of both mechanical prostheses and bioprostheses. It is commonly used to assess for complications such as restricted movement of leaflets, valve dehiscence (figure 14), pseudoaneurysms and paravalvular abscesses (3). With modern CT scanners, streak artefact from metallic components does not significantly impair the diagnostic quality of the images.

Further causes of cardiac valvular dysfunction include: valvular vegetations secondary to infective endocarditis, rare primary valvular tumours, intracardiac tumours and thrombi.
Fig. 1: Axial cardiac CT images of the aortic valve cusps demonstrating a normal aortic valve with three cusps (left), and a bicuspid valve with calcification of the two fused commissures (right).

Fig. 2: Axial cardiac CT images of the aortic valve cusps during systole demonstrating moderate stenosis of a bicuspid valve (left) and severe stenosis of a tricuspid valve (right).

**Fig. 3:** Axial cardiac CT images of the aortic valve cusps during diastole in two patients demonstrating a normal aortic valve (left) versus thickened valve cusps with a regurgitant orifice (right).

Fig. 4: Axial (left) and coronal (right) cardiac CT images of the aortic valve during diastole demonstrating prolapse of the coronary cusp resulting in mitral regurgitation.

**Fig. 5:** Four-chamber view cardiac CT images demonstrating a normal mitral valve during systole (left) and diastole (right).

**Fig. 6:** Two-chamber (left) and four-chamber (right) view cardiac CT images of the mitral valve acquired during systole, demonstrating a prolapsed mitral valve leaflet (left) and a flail leaflet (right). In both cases mitral regurgitation is present.

Fig. 7: Oblique (left) and two-chamber view (right) cardiac CT images acquired during systole demonstrating mitral valve leaflet perforation.

**Fig. 8:** Axial cardiac CT images demonstrating a normal pulmonary valve during systole (left) and diastole (right).

**Fig. 9:** Sagittal (left) and coronal (right) cardiac CT images of the pulmonary valve in two patients demonstrating a normal valve during diastole (left), and a systolic image demonstrating thickened valve cusps with narrowing of the opening area (right).

Fig. 10: Axial cardiac CT images of the pulmonary valve acquired during diastole demonstrating a normal valve (left) and thickened valve cusps with a large regurgitant orifice, in a patient with carcinoid heart disease (right).

**Fig. 11:** Four-chamber (left) and coronal (right) cardiac CT images of the tricuspid valve acquired during systole. Note the normal slender appearance of the valve leaflets.

**Fig. 12:** Cardiac CT images of the tricuspid valve cusps acquired during systole demonstrating incomplete coaptation of the valve leaflets and resultant tricuspid regurgitation.

Fig. 13: Cardiac CT images demonstrating a tilting disc valve during systole (left) and diastole (right).

**Fig. 14:** Cardiac CT image acquired during systole demonstrating a ball and cage prosthetic mitral valve with a paraprosthetic leak.

Conclusion

Cardiac CT is an increasingly valuable tool in the assessment of patients with VHD. It is of particular use in those with disease of the left sided valves however as we have illustrated, pathology of the pulmonary and tricuspid valves can be clearly demonstrated. Whilst echocardiography remains the primary imaging modality of the cardiac valves, the use of cardiac CT in selected cases is advantageous. It enables simultaneous assessment of the coronary arteries, however intracardiac and transvalvular haemodynamics cannot be evaluated at present. Although cardiac CT involves exposing patients to ionising radiation, the dose associated with retrospective gating is ever decreasing with advances in CT scanners.
References


