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Investigations in valvular heart disease

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Background

The management of valvular heart disease (VHD) depends on several questions:

- what are the symptoms (if any)?
- what, and how severe, is the lesion?
- how is the relevant ventricle coping?

Cardiac imaging is crucial for accurate determination of the nature and severity of the lesion, ventricular size and function, and is thus an indispensable component of the management of VHD. This article focuses on current imaging methods and which aspects each method best examines.

Chest X-ray

The chest X-ray can provide useful information on ventricular size, left atrial and pulmonary artery dilatation, and pulmonary congestion/oedema. For accurate cardiac assessment, however, it has been largely superseded by echocardiography and the chest X-ray is now rarely used as the sole investigation.

Echocardiography

Transthoracic echocardiography is well established as the main technique in the diagnosis of VHD. It should be considered in all patients with potential valve disease. It is a safe, non-invasive and often portable method for examining valvular structure and function, and the assessment of ventricular function (Fig 1). The portable nature of some echocardiography machines facilitates imaging in the resuscitation room or operating theatre if required, as well as in the outpatient department.

In addition to the nature and severity of valve disease, echocardiography provides anatomical information to allow decisions to be made on the optimal management for a diseased valve: for example, the degree of calcification and leaflet mobility in aortic stenosis (AS) or mitral stenosis (MS) may guide the choice between percutaneous valvuloplasty and surgical replacement. It may also reveal a non-valvular cause for a murmur or symptoms, such as an atrial myxoma mimicking MS.

Valvular stenosis

Several aspects can be assessed qualitatively in valvular stenosis, including the degree of valvular calcification, number of aortic leaflets, involvement of the commissures and, for MS, the subvalvar apparatus. The severity of stenosis can be assessed by measuring the velocity across the valve using Doppler echocardiography, with calculation of the pressure drop across the valve and the valve area.[1] In AS, left ventricular (LV) dysfunction may result in an underestimation of the stenosis severity. Dobutamine stress echocardiography may help to distinguish truly severe AS from 'pseudo-severe' disease due to poor cardiac output. It may also provide useful prognostic information.[2]

Valvular regurgitation

Anatomical information can be provided in valvular regurgitation, such as the affected leaflet(s) and the mechanism of regurgitation: for example, prolapsed or flail leaflets (Fig 2) or leaflet tethering in 'functional' mitral regurgitation (MR) due to poor LV contraction. An assessment of severity is also made, though care is required in this regard because many of the parameters can be affected by changes in haemodynamics, echocardiography machine settings or different imaging planes. Standardised techniques[3] are important, particularly for serial measurements.

Ventricular size and function

Ventricular size and function are routinely examined with echocardiography. They are important for determining the response of the ventricle to the pressure or volume load from the valve dysfunction. Both excessive dilatation in valve regurgitation and reduced LV function for most

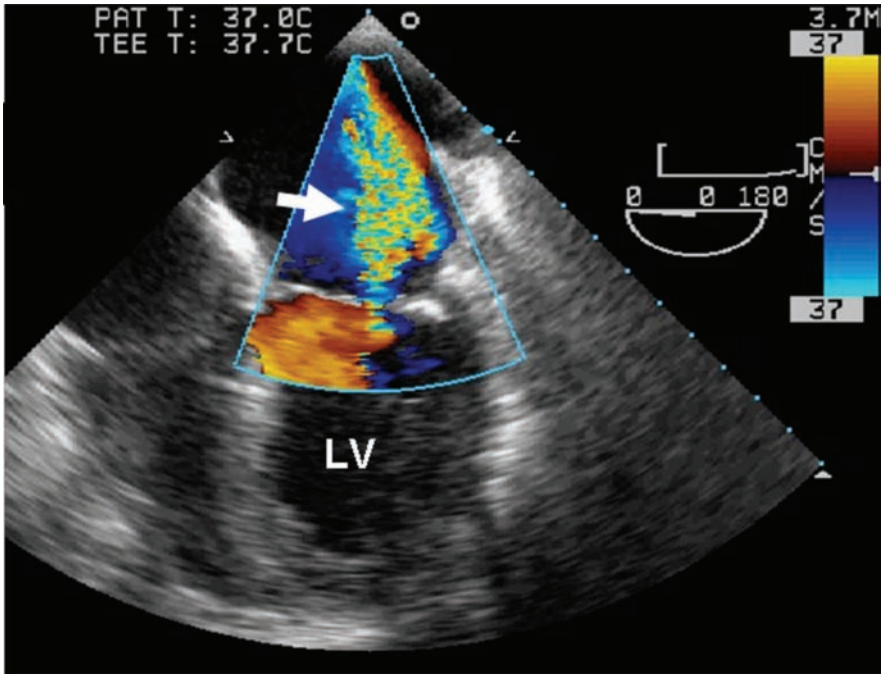

Fig 1. Transoesophageal echocardiogram showing a jet of moderate mitral regurgitation (arrowed) into the left atrium. LV = left ventricle.

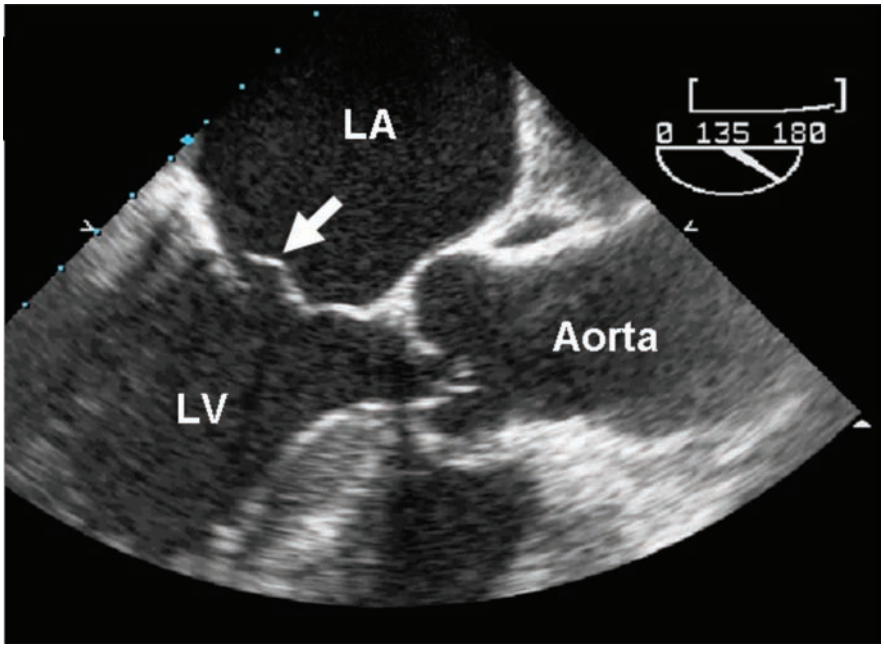

Fig 2. Transoesophageal echocardiogram showing prolapse of the anterior mitral valve leaflet (arrowed). The leaflet fails to coapt and is displaced towards the left atrium (LA). LV = left ventricle.

valve disease (excepting mitral or tricuspid stenosis) are important indicators of prognosis and usually an indication that surgery to repair or replace the valve is needed. Care is required to ensure accurate positioning for measurements, especially as serial echocardiograms are often undertaken. Standardised techniques have been published.[3]

Echocardiography is dependent on adequate acoustic 'windows' for good images. Some patients present particular problems, such as those with chronic respiratory disease, previous cardiothoracic surgery or extremes of body habitus. The reproducibility of echocardiographic measurements is also limited and care should be taken in interpreting small changes. Measurements of velocity and pressure gradient need accurate alignment, and changes in patient haemodynamics may significantly alter echocardiographic measurements. Some indices are less flow-dependent than others and these should be used whenever possible, eg direct planimetry of valve orifice area in stenotic valves. Management decisions based on a single parameter should be avoided; they should be informed by a combination of echocardiographic assessment (performed by an experienced operator) and the clinical scenario.

Transoesophageal echocardiography

Transthoracic echocardiography provides sufficient information in many cases but transoesophageal echocardiography (TOE) may provide important additional information. It is frequently used in the assessment of MR, as the close relationship between the lower oesophagus and the left atrium allows good visualisation of the valve anatomy and function to guide decisions on surgical strategy. The aortic valve and root are also well visualised with transoesophageal imaging. It should be considered in suspected cases of endocarditis[4] when transthoracic images are non-diagnostic and a high likelihood of endocarditis remains (eg bacteraemia with a likely organism).

TOE is routinely used in the intraoperative assessment of valve repair and replacement to ensure satisfactory results. Also, as minimally-invasive (including percutaneous) treatments for VHD are becoming more widely used, it has found another role in guiding these procedures. A nasal probe is now also available which offers advantages for procedures performed under conscious sedation rather than general anaesthesia.

In acute aortic dissection, TOE may be useful to assess the aortic root and valve, again potentially guiding surgical management, though the rise in blood pressure which may be associated with the procedure can occasionally be harmful.

Three-dimensional echocardiography

Three-dimensional (3D) echocardiography (both transthoracic and transoesophageal) is now more widely available. Recent advances in both equipment and software have made it more user-friendly and practical. Most studies of 3D echocardiography in VHD have examined the mitral valve, for which it can provide unparalleled views,

Key Points

- **Transthoracic echocardiography should be considered in all patients with potential valve disease**
- **Cardiac magnetic resonance provides accurate assessment of valvular function, particularly quantification of regurgitation, and accurate left ventricular mass and volumes**
- **Management decisions based on a single parameter should be avoided: clinical assessment by an experienced physician is essential, and a significant disparity between this and imaging should prompt further consideration**
- **Cardiac computed tomography may be used to exclude coronary disease prior to valve surgery in certain patients**

KEY WORDS: cardiac investigations, cardiovascular magnetic resonance, echocardiography, valve disease

but the aortic valve can also be assessed well. In addition, the measurement of LV volumes using 3D echocardiography is one of the most useful aspects of this technique, with very good accuracy and reproducibility.[5–7]

Cardiac magnetic resonance

Cardiac magnetic resonance (CMR) is becoming more frequently used in the assessment of VHD. It provides quantitative and reproducible measures of both stenosis and regurgitation, as well as accurate measurement of the volume and function of both ventricles.[8] The assessment of the right ventricle is difficult by other methods but is a strength of CMR. A unique feature of CMR is the ability to measure flow through an image slice, with good agreement with invasive measurements and *in vitro* testing,[9,10] allowing the quantification of regurgitation rather than a qualitative assessment of severity. CMR can also accurately assess the aortic root and ascending aorta, important aspects in aortic valve disease. CMR can thus provide a comprehensive and accurate evaluation of the severity of valve disease and the consequences for the ventricle. Detailed information on valve leaflet anatomy is less well assessed however, and TOE provides higher resolution imaging.

Measurement of forward and reverse flow across the aortic or pulmonary valves allows the quantification of aortic/pulmonary regurgitation (Fig 3), providing both regurgitant volume and fraction (regurgitant flow/forward flow). Mitral and tricuspid regurgitation are quantified by subtracting the aortic or pulmonary forward flow from the LV or right ventricular stroke volume, respectively (measured accurately with CMR). The difference provides the volume of regurgitation, and regurgitant fraction can also be calculated (regurgitant volume/stroke volume). The high mobility of the mitral and tricuspid valves and turbulent flow across them makes direct flow measurement difficult. In valve stenosis, valve area can be assessed by direct planimetry rather than by calculation (Fig 4), usually providing

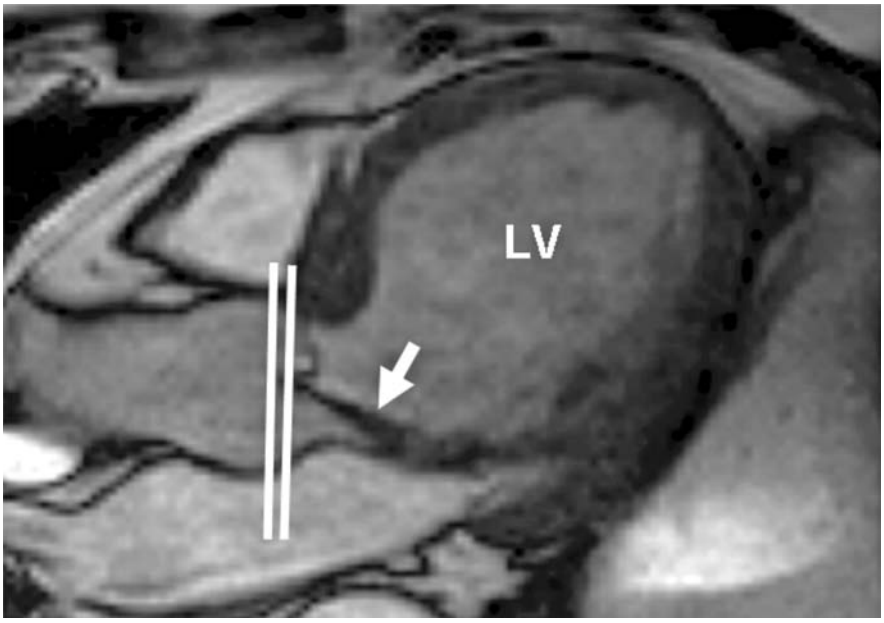

Fig 3. Cardiovascular magnetic resonance image in the left ventricular outflow tract (3-chamber) view in diastole, showing an eccentric jet of aortic regurgitation (arrowed) and the position of the image slice for through-plane flow measurement (parallel lines). LV = left ventricle.

Fig 4. Cardiovascular magnetic resonance image through the tips of a stenotic aortic valve (arrowed). Direct planimetry of the valve area is straightforward.

a better assessment of severity with CMR than velocity across the valve – velocity measurements lack the spatial and temporal resolution of Doppler echocardiography and may underestimate valve severity. LV mass can also be measured accurately, in addition to volumes and function.

Limitations

At present, the limited availability of CMR restricts its use in VHD, and it has a relatively high cost compared with echocardiography. Acquisition and analysis times are also longer, making it less attractive for outpatient use, though developments in scanners and software technology are likely. Arrhythmias (eg atrial fibrillation) may impair image quality and affect the accuracy of flow measurements, though newer imaging sequences can cope with this common problem. Claustrophobic patients can often be scanned by experienced personnel, though about 1–2% of patients may find this too difficult.

CMR remains mostly contraindicated in the presence of certain ferromagnetic implants, including cerebral aneurysm clips and cardiac pacemakers/defibrillators. However, prosthetic (including metallic) valves and coronary stents are almost never a problem.

Cardiac computed tomography

Although cardiac computed tomography (CCT) is increasingly used in the context of coronary artery disease, its use in VHD is limited. It can provide morphological information on the valves and their associated structures, particularly calcification (Fig 5),[11,12] as well as volume and mass measurements. However, it does not provide haemodynamic information, is sensitive to arrhythmias and requires a slow heart rate (often necessitating beta-blockade or other rate-slowing medication). CCT also involves ionising radiation, though newer scanners utilise techniques to significantly reduce the dose. A major advantage of CCT may be to exclude coronary disease prior to valve surgery.[4]

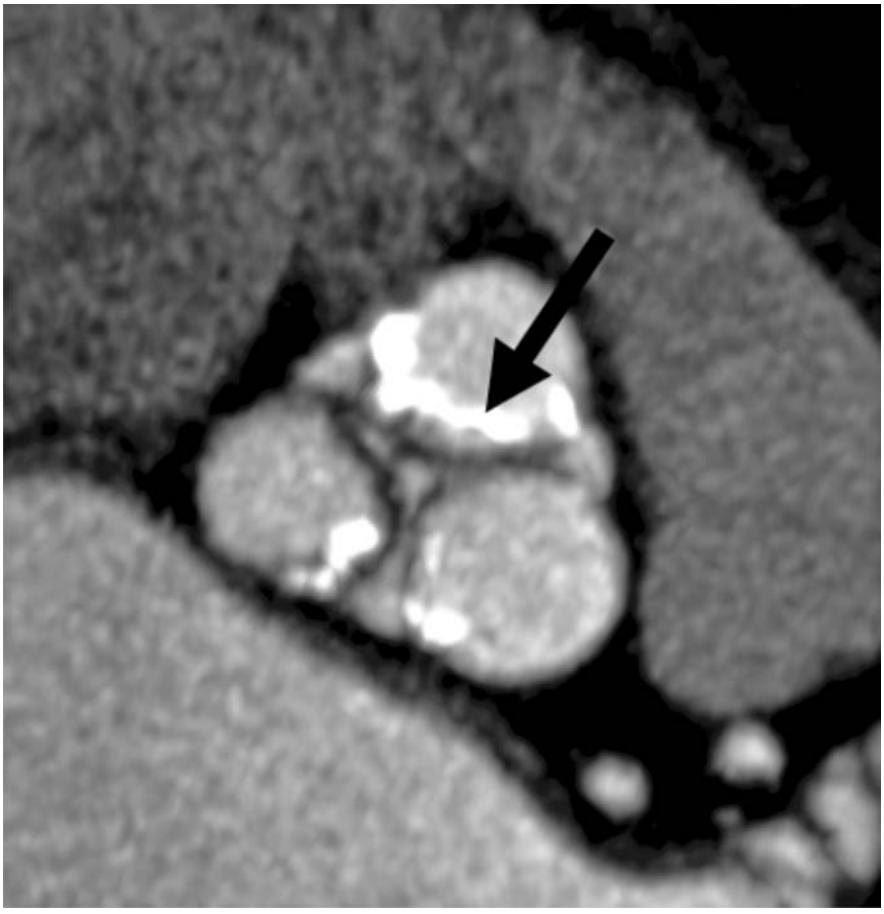

Fig 5. Computed tomographic image of an aortic valve (en-face view), showing leaflet calcification which appears white on the image (arrowed) (courtesy of Dr Ed Nicol, John Radcliffe Hospital, Oxford).

Exercise testing, fluoroscopy and invasive assessment

Exercise treadmill testing may be used to unmask symptoms and also to have a role in risk stratification in AS.[13,14] Fluoroscopy can be used to assess the motion of prosthetic valve leaflets and also demonstrate calcification. Coronary angiography may be performed to assess the need for cardiac revascularisation at the time of valve surgery, but the routine use of cardiac catheterisation for the assessment of VHD is no longer necessary and non-invasive methods may be all that is required.[4] Left and right heart catheterisation is still occasionally useful in the assessment of MS or MR. Aortography can provide a useful assessment of aortic regurgitation but this has largely been superseded by echocardiography and CMR.

Biomarkers

Recent attention has focused on biomarkers to assess both severity and prognosis in VHD. B-type natriuretic peptide has shown some promise in both aortic and mitral valve disease,[15–18] with a suggestion that it is able to predict outcome and the need for valve surgery. However, numbers in the studies have been small and further evaluation is needed before the place of these tests in the management of patients with VHD becomes clear.

Conclusions

In the early 21st century, echocardiography remains the cornerstone of imaging in VHD. Recent advances including 3D echocardiography are emerging as useful

additional techniques. CMR provides an accurate assessment of valvular function, particularly quantification of regurgitation and accurate LV mass and volumes. B-type natriuretic peptide levels may provide additional information on severity and prognosis.

Clinical assessment by an experienced physician remains essential, however, particularly when there is disparity between symptomatic status and investigational findings and when intervention is contemplated.

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