Review

Assessment of Valvular Heart Disease by Cardiovascular Magnetic Resonance Imaging: A Review

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CMR is a comprehensive non-invasive tool capable of evaluating all aspects of valvular heart disease. It has advantages over echo including direct quantification of regurgitant lesions, highly accurate assessment of ventricular size and function, visualisation myocardial scar, and interrogation of extracardiac abnormalities. Although these gains can be realised with current scanning techniques, CMR's full potential has yet to be realised, and further studies of clinical outcomes are needed before CMR data can be integrated into the management algorithms for patients with significant valvular lesions.

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Introduction

Valvular heart disease is increasing in prevalence [1], and continues to present clinicians with diagnostic and therapeutic challenges. Echo is the principal non-invasive tool for initial evaluation and longitudinal monitoring of patients with significant valvular heart disease. However despite impressive gains in functionality and image quality, echo remains limited by poor acoustic windows, and is dependent on the skill and experience of the sonographer. Alternative imaging modalities can evaluate specific aspects of valvular disease. Multi detector-row computed tomography can provide high spatial resolution anatomical images of valves and associated structures [2,3], but has inadequate functional information. Cardiac catheterisation remains the "gold standard" for haemodynamic measurement [4], but provides limited structural data and is invasive. Both techniques require significant exposure to ionising radiation. By contrast cardiovascular magnetic resonance (CMR) can provide a comprehensive non-invasive assessment of cardiac structure and function in the setting of valvular heart disease, without exposure to ionising radiation. The aetiology and severity of the valvular dysfunction and the consequences of it can be accurately determined. Indeed CMR offers unique information including quantification of valvular regurgitation and tissue characterisation, which may have added clinical benefit over echo. The purpose of this review is to summarise the role of CMR in the evaluation of patients with valvular heart disease, and to highlight the potential areas of incremental value over more widely used investigations.

Imaging Principles and Sequences

An optimal non-invasive evaluation for valvular heart disease should include accurate assessment of valvular morphology, quantification of the severity of valvular dysfunction, determination of its aetiology, assessment of the consequences for the heart from the valve lesion including measurement of ventricular volumes and function, and evaluation of haemodynamic abnormalities. Additional information should be obtained such as great vessel anatomy, and the presence of coronary disease and myocardial scar. Cardiac magnetic resonance uses a variety of pulse sequences within the external magnetic field to address most of these key issues. Each pulse sequence is a combination of changing magnetic gradients and radiofrequency pulses created to acquire information on specific aspects of tissue characterisation or blood flow.

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Functional Anatomy

The majority of morphologic and functional information is obtained using cine CMR sequences. The most widely used of these is "steady state free precession" (SSFP), which is characterised by high intrinsic contrast between blood pool and the surrounding structures, and excellent signal-to-noise ratios [5] (Fig. 1). The use of SSFP sequences has largely replaced spoiled gradient echo sequences, although the latter remain useful for imaging the extent of flow disturbance. Both SSFP and gradient echo sequences produce a two-dimensional (2D) image in operator-prescribed planes with 20–40 frames (termed 'phases') throughout the entire cardiac cycle. Each cine image has a temporal resolution of approximately 30 ms, and is acquired during a breath hold by ECG gated imaging over several cardiac cycles. The in-plane spatial resolution of the SSFP sequences is typically 1–2 mm, which is sufficient to assess all aspects of valvular anatomy and pathology. Although echo may have greater absolute temporal and spatial resolution, the planning of the CMR imaging planes is not limited by acoustic windows. This is particularly useful for right sided valve lesions, especially assessment of the pulmonic valve [6], but even for left heart valve lesions such as mitral valve prolapse [7], the information obtained regarding leaflet pathology and jet direction may be comparable to transoesophageal echo. However the need to acquire cine images over several cardiac cycles may result in sub-optimal visualisation of small or more chaotically mobile objects such as vegetations [8] or torn mitral chordae [7]. Real-time CMR imaging allows much faster acquisition of each image, potentially avoiding this limitation [9], but the trade-off is poorer spatial resolution which limits its utility for small structures. It should also be noted that dysrhythmias can result in degradation of image quality in CMR. This is most troublesome in patients with frequent ectopy or atrial fibrillation, both of which are more prevalent in valvular heart disease.

SSFP sequences form the basis of the quantification of ventricular volumes and myocardial mass, and this analysis is widely accepted as the "gold standard" for such measurements [10]. Additional anatomical information may be obtained from non-cine pulse sequences. T1-weighted turbo spin echo sequences may be used in conjunction with SSFP sequences for measurement of great vessel dimensions, and in combination with T2-weighted and 'fat sat' sequences can provide insights into the tissue characterisation of valvular masses [11]. Delayed or 'late' enhancement inversion recovery gradient echo sequences (following administration of intravenous gadolinium chelates) are useful for detecting atrial [12] and ventricular [13] thrombi, or coexisting myocardial infarction or focal fibrosis [14].

Velocity and Flow

Visual assessment of turbulent flow is feasible with the cine pulse sequences described above, through visualisation of signal voids due to spin dephasing in moving protons [15]. The location and directionality of regurgitant or stenotic jets can be assessed, and this in turn assists in planning the placement of subsequent velocity-encoded images. Gradient echo sequences are more sensitive than SSFP sequences for evaluating the presence and magnitude of regurgitant jets [16], and this sensitivity is increased with lengthening echo time [17,18]. Signal voids seen on SSFP imaging are substantially related to the acceleration of blood rather than the velocity alone, and may underestimate the severity of a regurgitant lesion.

Accurate quantification of blood flow and velocity, however, requires the use of phase-contrast pulse sequences (also termed velocity-encoded cines) [19]. The non-invasive measurement of flow is a unique advantage of CMR. Protons moving in a magnetic field gradient acquire a shift in the phase of their rotational spin as compared with stationary protons, and the magnitude of this phase shift is proportional to their velocity. By producing images from the phase information, velocity can be measured [20], and is visually displayed in greyscale or colour images (Fig. 2A). The phase-contrast sequence requires the operator to input the maximum velocity associated with a 180° phase shift (the encoding velocity) appropriate to the clinical situation. Setting too high a value decreases relative flow amplitudes, impairing accurate interpretation, whilst too low a velocity will lead to aliasing (analogous to pulse wave Doppler echo) [20]. The operator must also prescribe the imaging plane, as standard phase contrast sequences only measure velocity in one direction. Normally, the image plane is positioned perpendicular to the direction of blood flow, allowing measurement of velocity

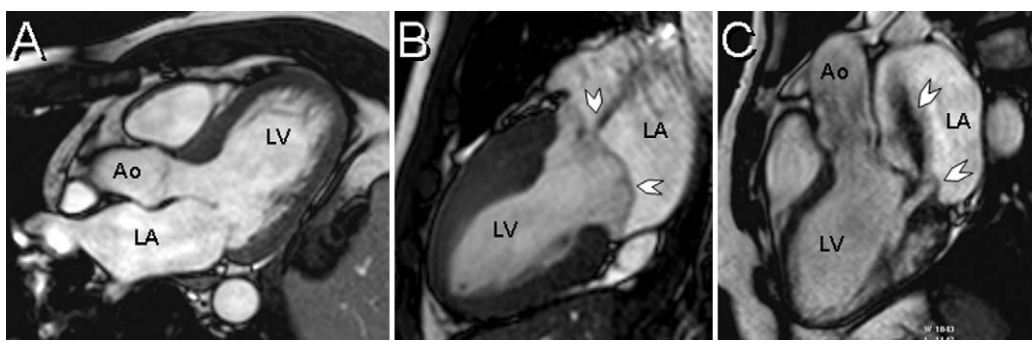

Fig. 1. *CMR cine imaging in valvular heart disease. Steady state free precession images in 3 patients demonstrating (A) a structurally normal mitral valve, (B) bileaflet mitral valve prolapse with mild MR and (C) a severely myxomatous mitral valve with posterior leaflet prolapse and severe MR.*