

Cardiovascular magnetic resonance for selecting anatomically suitable patients for transcatheter aortic valve implantation: should it be rolled out or ruled out?

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Transcatheter aortic valve insertion (TAVI) has transformed the management of severe aortic stenosis (AS) in high and intermediate surgical risk patients.¹ The role of multi-modality imaging is central to AS diagnosis, procedural guidance, and the follow-up of TAVI patients (Table 1). Echocardiography and multi-slice computed tomography (MSCT) have long been the cornerstone modalities of choice for TAVI work-up.¹ However, the usefulness of these modalities can be limited in certain patients, including patients with contrast allergy, poor acoustic echocardiographic windows, and severe renal disease. The case report by Raby *et al.*² in the current edition of EHJ eloquently describes the use of contrast-free cardiovascular magnetic resonance (CMR) as an alternative to MSCT for TAVI planning in a patient with concerns over contrast agent use secondary to renal impairment. The patient had an excellent clinical outcome. The role of CMR in AS assessment is acknowledged in the most recent European guidelines.¹ CMR can be a complementary imaging modality and/or alternative to echocardiography and MSCT.¹ However, its exact role in TAVI is still emerging.³

The case report by Raby *et al.*² demonstrates CMR measurements of ostial height, aortic root dimensions, and annular measurements for valve sizing. In addition, CMR was used for vascular access assessment.² The case report is in keeping with previous studies that showed excellent correlation between CMR and MSCT on valve sizing⁴; and a second study that demonstrated the feasibility of assessing

vascular access lumen dimensions, atherosclerosis burden, and vessel abnormalities.⁵ However, CMR is inferior to MSCT in assessment of calcification.¹ The degree of calcification in the aortic valve (AV) and access vessels is important for procedure planning. It can be difficult to clearly appreciate calcification on CMR because calcified tissue produces little signal. The assessment of calcification burden aids in risk stratifying for potential damage to access vessels. However, with improvement of TAVI valves and deployment system design this is likely to become less important in the future. Furthermore, AV calcium provides information not only on AS severity but asymmetrical distribution. Asymmetrical distribution can predict risk of paravalvular leak. There are alternative CMR techniques for assessment of AS severity including AV area and gradient as described in the case report. However, calcium and any asymmetry cannot be clearly defined on CMR.

The case report used echocardiography for evaluation of cardiac structure, ventricular function, and other valves. This is in keeping with guideline practice. CMR is an alternative image modality for this assessment. CMR has unlimited imaging planes, offers three-dimensional reconstruction, and can be used in patients with poor echocardiography acoustic windows. CMR is the gold standard for ventricular function. It can act as a discriminator when there are conflicting findings or complex AV disease, such as ambiguity of the degree of AS or stenosis at more than one level.

The case report describes the typical patient referred for TAVI. The patient was elderly comorbidities and high risk for definitive AS surgery. Calcific AS is considered a disease of the elderly.⁶ The indications for TAVI were once limited to these high surgical risk patients. However, the indications for TAVI are expected to increase. TAVI

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Table 1 Non-invasive imaging modalities used for the selection of anatomically suitable patients for transcatheter aortic valve implantation in contemporary practice

	TTE/TOE	MSCT	CMR
AV stenosis (gradient and valve area)	+++	+	+++
AV regurgitation and paravalvular leak	++	—	+++
AV morphology (bicuspid vs. tricuspid)	++	+++	+++
AV annulus dimensions and perimeter	++	+++	+++
Aortic root and ascending aorta dimensions	++	+++	+++
Coronary height	±	+++	+++
Coronary artery disease severity/ischaemia assessment	++	+++	+++
TAVI vascular access	—	++	+++
Calcification (valve and vascular)	++	+++	+
Assessment of LV function and other valves	+++	+	+++
Myocardial structure (infarct/fibrosis/amyloid infiltration)	+	—	+++
Patients with renal impairment (contrast nephrotoxicity)	+++	±	++
Patients at high risk of radiation exposure	+++	±	+++
Patients with PPM, ICD and other implantable devices	+++	+++	±
Availability and ease of use	+++//+	++	+
Cost consideration	+++//++	++	++

+++ high suitability, ++ moderate suitability, + low suitability and — unsuitable.

AV, aortic valve; CMR, cardiovascular magnetic resonance; ICD, implantable cardioverter-defibrillator; LV, left ventricle; MSCT, multi-slice computed tomography; PPM, permanent pacemaker; TAVI, transcatheter aortic valve insertion; TOE, transoesophageal echocardiography; TTE, transthoracic echocardiography

has demonstrated promise in intermediate-risk patients,⁷ valve-in-valve treatments for failing bio-prosthesis, and native pure aortic regurgitation.⁸ Despite the increase in TAVI procedures and requirement for imaging, the use of CMR in this evolving cohort of patients' is uncertain. Primarily due to cost, availability, and speed. However, this cohort will likely have a high proportion of comorbidities too, and therefore possibly require bespoke imaging management which could be provided by CMR.

One group likely to benefit from CMR are congenital patients including patients with a bicuspid AV. A bicuspid AV can lead to premature leaflet damage and requirement for AV intervention. Bicuspid AV intervention can include TAVI. Patients with complex congenital anatomy need lifelong imaging follow-up. In many congenital centre's, patients are often followed-up with CMR for detailed surveillance. In these relatively young patients', the lifetime accumulation of radiation dose needs to be considered. CMR offers a radiation free alternative.

CMR has limitations. It often requires breath-holding sequences, and greater patient cooperation. This can be difficult in patients with symptomatic comorbidities, such as decompensated heart failure secondary to AS. Some CMR vendors and sequences do offer faster acquisition times. Sequences do exist to assess the ventricle function in a single breath hold, and work continues to accelerate acquisition times. A second limitation is temporal resolution. Temporal resolution with CMR is inferior to echocardiography. This makes it difficult to assess small moving structures, such as lesions suspicious for vegetation or leaflet thrombus. Finally, CMR requires operator experience for highly technical scans and accurate measurements. For example, AS velocities can be underestimated if the imaging plane is positioned too far downstream of the AS jet, and artefact created by medical implanted devices can be minimized using different sequences to optimise the image produced.

The non-contrast protocol used in the case report provided sufficient detail for TAVI planning. It was mentioned that gadolinium-based contrast agents (GBCA) can offer other useful information, such as contrast-enhanced angiography for further vascular assessment and left ventricular myocardial fibrosis evaluation which provides prognostic value.⁹ Other prognostic markers include left ventricular remodelling, tissue characterization, and myocardial ischaemia. Myocardial ischaemia assessment is a first pass perfusion study under vasodilator stress to assess suspected flow limiting coronary artery disease (CAD). CAD assessment is required for TAVI planning and typically patients have angiography requiring iodinated contrast. The patient reported had moderate to severe CAD on angiography in recent years. The use of GBCA for ischaemia assessment would have been considered. Earlier linear GBCA products have been implicated in the development of nephrogenic systemic fibrosis (NSF) in patients with severe renal impairment which led to reduced use. This practise may prevent clinical benefit. More recent clinical and experimental studies demonstrate that newer cyclic GBCA have an extremely low risk for NSF in the setting of severely decreased glomerular filtration rate and should be administered if clinically indicated.⁸ NSF is now rarely reported.⁸ Its use can be justified for clinical benefit if required to provide a robust road map for TAVI, ischaemia evaluation, assessment of myocardial infarction, or infiltrative cardiomyopathy including amyloidosis. Amyloidosis is not uncommon in the contemporary TAVI cohort.

The clinical outcome in the case report provide optimism for CMR in TAVI. In the future, there might even be potential for non-contrast, radiation free and real-time-CMR-guided TAVI procedures. TAVI has been successfully implanted in animal models using real-time CMR and custom-engineered delivery systems with

non-ferromagnetic materials.^{9,10} Real-time CMR TAVI in humans is not possible at present because CMR conditional equipment is unavailable commercially. It is unclear whether improved soft-tissue visualisation and lack of contrast confer benefit.

Overall, the case report demonstrates that CMR offers complementary and/or alternative information to echocardiography and MSCT for AS and TAVI work-up. However, we must remind ourselves that this is a single case from a highly specialised centre with expert experience. Further prospective research is needed in a multicentre setting to establish if there is expertise and a role for CMR in TAVI work-up. Health providers need to be vigilant to avoid duplication of imaging that would increase cost and inconvenience patients. With the growing demand for TAVI, there is clinical equipoise for this research. Ultimately unless CMR can be shown to lead to safer and better clinical outcomes for patients under consideration for TAVI, its role will remain debatable, and confined to a small cohort of patients.

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