EACVI
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Cardiovascular Imaging

Protocols in CMR

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Introduction

CMR is an imaging modality that is being increasingly used and has seen rapid developments. CMR is used to visualise and assess the structure and function of the heart (1). Reproducible and accurate measurements of the atria, ventricles and left ventricular, LV mass can be obtained and it is used to image various cardiac and cardiac related pathologies. In a single scan setting ventricular volumes and function can be assessed It is the gold-standard for volumetric analysis. Myocardial fibrosis, iron loading, flow quantification, tissue characterisation and myocardial perfusion can all be assessed (2). The advent of CMR has changed the work-up of patients with suspected cardiac and cardiac related pathologies, aiding diagnosis and assisting to determine appropriate treatment paths and therapeutic response and risk stratification.

The use of standardised tailored CMR protocols, tailored to the clinical question and pathology being evaluated is critical for accurate diagnosis, consistent reporting and patient management and disease monitoring. Such protocols have been developed and are updated by the European Society of Cardiology, especially through European Association of Cardiovascular Imaging (EACVI) and Society of Cardiovascular Imaging, SCMR.

This article gives a brief overview on the importance of such standardised protocols, their links to some specific pathologies and their relevance to common clinical questions.

Key Words

CMR Protocols, cine imaging, parametric mapping, LGE, perfusion, flow imaging.

Main Body

CMR may be undertaken at both 1.5T and 3T magnetic field strengths. Imaging at 3T brings some benefits such as improved signal to noise ratio but difficulties with ECG triggering may be more common on 3T compared to 1.5T due to the magneto hemodynamic effect. The advantages and disadvantages of CMR imaging at 3T have been reviewed (3).

CMR protocols use a variety of sequences. These provide information on:

- myocardial morphology
- function
- tissue characterisation
- myocardial perfusion
- coronary anatomy

A standard CMR examination involves:

- white or black blood imaging: localising scans in three orthogonal planes. These provide information on cardiac anatomy and are used for subsequent acquisition planning
- cine imaging (balanced steady-state free precession, bSSFP or gradient echo, GRE sequences): acquired in standardised cardiac planes and are essential for assessing ventricular volumes, function, assessing regional wall motion abnormalities. Information and direction on the planning of these and all cardiac planes is contained in ESC Congenital Heart Disease Pocket Guide.
- tissue characterisation: black-blood T1 TSE and STIR imaging – important to assess the tissue signal intensities of differing cardiac masses
- late gadolinium enhancement, LGE: used to evaluate myocardial or fibrosis through the injection of gadolinium based contrast agents. Sequences used are typically phase sensitive recovery, PSIR, sequences. Different patterns of LGE are indicative of differing pathologies and conditions. Correct selection of inversion time, TI, critical to ensure nulling of normal myocardium.
- parametric mapping: assessment of myocardial tissue characteristics, including inflammation and oedema and fibrosis. They are especially useful in the diagnosis

of conditions associated with oedema, such as myocarditis and also in the diagnosis in amyloidosis and Fabrys' disease. T2* mapping especially useful in

- the assessment of iron overload, such as in haemochromatosis and thalassaemia
- phase contrast flow imaging: Quantify blood flow within the heart and great vessels and valve assessment.
- perfusion imaging: used to assess myocardial blood flow in the setting of the detection of ischaemia.

These generalised protocols can be tailored to individual clinical questions. For example, in the setting of a suspicion of myocarditis sequences for the assessment of oedema, such as T1 and T2 mapping should be included. CMR with LGE and T2 mapping can be used in the diagnosis of myocarditis, for example.

In the assessment of ischaemic heart disease, LGE is useful for revealing areas of infarct and cine and perfusion imaging assess function and myocardial ischaemia. The size and extent of infarct that may be present may also be assessed.

In HCM and DCM, CMR protocols should include LGE and cine imaging to allow for assessment of outflow tract obstruction. The presence and extent of LGE has been shown to be a good predictor of outcomes for patients with non-ischaemic DCM and HCM (4, 5).

A typical CMR protocol may include axial white blood imaging, followed by long and short axis cine imaging using balanced steady-state free precession sequences. These are used to assess cardiac function and volumetric analysis undertaken using use. Flow imaging of the aortic and pulmonary valves may be done to fully interrogate these valves, followed by parametric mapping. Stress perfusion imaging may be undertaken, if clinically indicated, followed by early and late gadolinium enhancement, LGE imaging. LGE is undertaken approximately 8-10mins post contrast injection and optimum TI selection is used throughout it. The short axis cine imaging can be undertaken between early and LGE imaging. A protocol such as this may be undertaken in 30 minutes.

Upon review of images and during the CMR examination imaging protocols may have to be amended, for example, if there is suspected right sided pathology axial imaging of the right ventricle may be undertaken, as may cine imaging of the pulmonary arteries. Or further valvular views may be needed, such as, cross-cut cine imaging of the aortic valve in cases of stenosis and/or regurgitation.

The ESC, with EACVI has published a series of "CMR Pocket Guides" which provide practical day-to-day advice, tips and tricks in image acquisition and CMR protocols.

Conclusion

CMR provides detailed insights into myocardial structure, function and tissue characteristics through tailoring imaging protocols to specific pathologies. These protocols are continuously refined through continuous research and consensus statements to ensure optimal image quality, accurate quantitative data and clinically relevant insights across a wide spectrum of cardiovascular disease.

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SIG Radiographer Overview of contrast Agents

SIG Radiographer Overview of Pathologies

SIG Radiographer Overview of T1 Mapping

SIG Radiographer Overview of Perfusion