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Cardiovascular Magnetic Resonance in Cardiology Practice: A Concise Guide to Image Acquisition and Clinical Interpretation

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A B S T R A C T

Cardiovascular magnetic resonance plays an increasingly important role in routine cardiology clinical practice. It is a versatile imaging modality that allows highly accurate, broad and in-depth assessment of cardiac function and structure and provides information on pertinent clinical questions in diseases such as ischemic heart disease, nonischemic cardiomyopathies, and heart failure, as well as allowing unique indications, such as the assessment and quantification of myocardial iron overload or infiltration. Increasing evidence for the role of cardiovascular magnetic resonance, together with the spread of knowledge and skill outside expert centers, has afforded greater access for patients and wider clinical experience. This review provides a snapshot of cardiovascular magnetic resonance in modern clinical practice by linking image acquisition and postprocessing with effective delivery of the clinical meaning.

Resonancia magnética cardiovascular en la práctica cardiológica: una guía concisa para la adquisición de imágenes y la interpretación clínica

Palabras clave:
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Cardiología
Miocarditis
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R E S U M E N

La resonancia magnética cardiovascular está adquiriendo un papel cada vez más relevante en la práctica clínica habitual en cardiología. Se trata de una modalidad de diagnóstico por imagen versátil que permite una evaluación exacta, amplia y profunda de la función y la estructura cardiacas y que aporta información sobre cuestiones clínicas relevantes, en enfermedades como la cardiopatía isquémica, las miocardiopatías no isquémicas y la insuficiencia cardiaca, a la vez que permite indicaciones especiales, como la evaluación y/o cuantificación de la sobrecarga de hierro o la infiltración miocárdica. La creciente evidencia que respalda el papel de la resonancia magnética cardiovascular, junto con la difusión del conocimiento y la pericia en su uso fuera de los centros expertos, ha permitido un mayor acceso de los pacientes a esta técnica y la obtención de una experiencia clínica más amplia. En esta revisión se refleja la situación de la resonancia magnética cardiovascular en la práctica clínica moderna relacionando la adquisición y el posprocesado de las imágenes con una descripción efectiva de su significado clínico.

INTRODUCTION

Standardized cardiovascular magnetic resonance (CMR) acquisition protocols are designed to purposefully address clinical questions. Contemporary use of CMR in routine clinical practice has been shaped through the efforts of standardization from image acquisition to post-processing,[1,2] to obtain the wealth of clinical information that affects patient management and outcomes, supporting reimbursement.[3] Extensive and lengthy imaging acquisitions and overly descriptive CMR reports have been scrutinized to clinically relevant outputs, with essential measurements and information serving to answer the clinical question. Two imaging protocols will clarify most pertinent questions in modern clinical cardiology workflows:

1. *"Left ventricular (LV) function and scar/fibrosis protocol"*. This protocol assesses cardiac volumes and function by cine imaging, and the presence, extent and the type of scar/fibrosis by late gadolinium enhancement (LGE) (Figure 1A).
2. *"Myocardial stress perfusion protocol"*. This protocol is added to the above basic framework when required by the symptoms, suggesting the presence of myocardial ischemia or, where

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Abbreviations

CMR: cardiovascular magnetic resonance
LGE: late gadolinium enhancement

relevant, the need for guidance by coronary intervention (Figure 1B).

Because of their ease and robustness, these 2 CMR protocols can be performed in most clinical departments within 20 and 45 minutes, respectively, delivering diagnostic images in nearly all patients except for a small number not able to benefit from magnetic resonance imaging (MRI), either due to contraindications (such as medical devices) or large body size. Such short imaging times increase patient comfort, efficient clinical throughput, and experience in image acquisition and interpretation. A handful of meaningful departures from this basic scheme together with their clinical intent are included in the second part of this review.

CARDIAC VOLUMES AND FUNCTION

Unlimited by acquisition windows, CMR can provide an overview of cardiac morphology, as well as of the relationships of the cardiac chambers with the great vessels and other thoracic structures. The mainstay of radiological practice, the black-blood sequences, where the blood signal is suppressed to highlight the vascular and myocardial structures, have been replaced by faster gradient echo sequences, and eventually, by balanced sequences (steady-state free precession sequences). These modern sequences allow rapid acquisition, obtaining multiple consecutive images that can be displayed in "still" or "moving-cine" mode to show cardiac movement.

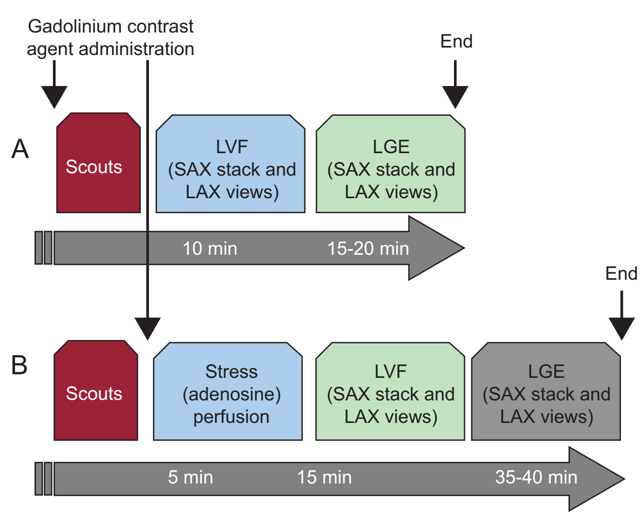

Figure 1. Basic cardiovascular magnetic resonance protocols of everyday clinical routine based on the robustness and maximized information output of imaging applications. A: Left ventricular function and late gadolinium enhancement represents a standard assessment of cardiac function and structure and recognition of underlying cardiomyopathy, based on the presence and pattern of late gadolinium enhancement. B: Addition of myocardial stress (adenosine) perfusion to the basic scheme support assessment of myocardial ischemia when mandated by the typical angina symptoms. Omission of rest perfusion is based on the negligible additional information in the presence of late gadolinium enhancement, which reduces the scan time and contrast dose. LAX, long axis; LGE, late gadolinium enhancement; LVF, left ventricular function; SAX, short axis.

Cine (balanced) imaging is the gold standard of the quantification of biventricular volumes and function, as well as LV mass, overcoming the limitations of echocardiography such as poor acoustic window or geometrical assumptions that lead to inaccuracies and lower reproducibility of the measurements. An excellent definition of endocardial and epicardial borders translates into higher reliability of the obtained values, with excellent interobserver and intraobserver variability (interobserver variability of 4.4% for ejection fraction, 6.3% for diastolic volume, and 8.6% for systolic volume; intraobserver variability 4.0%, 3.6% and 6.5%, respectively).[4] In addition to chamber quantification, cine imaging allows inspection of cardiac structure and regional wall motion, accurately and reproducibly.[5] Because these parameters provide the basis of clinical management decisions, such as establishing diagnosis (eg, dilative cardiomyopathy[6]) or serving as a guide to treatment (eg, device therapy[7]), the accuracy of the measurements is key. A further advantage is assessment of the right ventricle, which is a challenge in echocardiography due to its complex shape, which does not adapt to any geometrical model.

Cine images are obtained in a routine adult patient, as shown in Figure 2:

1. A contiguous stack of short axis slices, defined by the centerline long axis of the LV
2. Perpendicular long axis views (2-, 3- and 4-chamber views).

The coverage of the short axis stack will include both ventricles in their entirety. This acquisition scheme or geometry is followed in the subsequent LGE acquisition, allowing for side-by-side assessment of findings. Standardized post-processing recommendations outline the principles of quantification, which are adopted by approved post-processing software,[2] and allow longitudinal comparisons between observers and imaging centers, as well as comparison with the published normal values.[8–11] A complete short axis stack serves as the basis for quantification of biventricular volumes and function, as well as LV mass, with papillary muscles included in the blood volume as per convention. Delineation of contours in the basal slices can be challenging due to partial cuts through the structures, in which side-referencing with long axis views provides very helpful guidance.

MYOCARDIAL SCAR OR FIBROSIS BY LATE GADOLINIUM ENHANCEMENT

Gadolinium contrast-based imaging has unique ability to directly visualize the key extracellular pathophysiological substrates in the development of heart disease–myocardial scar/fibrosis.[12] Late gadolinium enhancement exploits the differences in regional and temporal distribution of gadolinium-based contrast agents between different types of tissues such as healthy myocardium vs necrotic myocardium or scar tissue. Gadolinium is not imaged directly; imaging contrast is based on the alteration of the magnetic properties of tissue in the presence of the gadolinium, by "shortening" (acceleration) of the longitudinal relaxation within the tissues where gadolinium-based contrast agents accumulate. The LGE is best suited to visualization of well-demarcated regional changes, such as post-infarct myocardial scar[13] (Figure 3). This phenomenon can be typically observed 10 min to 20 min after administration of gadolinium-based contrast agents using T_1-weighted inversion recovery gradient-echo sequences. The imaging contrast of black and white, ie, healthy (remote) myocardium and post-infarct scar, respectively,