Establishing a Cardiac MRI Program: Problems, Pitfalls, Expectations

Michael K. Atalay, MD, PhD[ab]

Magnetic resonance imaging (MRI) has been used to evaluate the cardiovascular system for almost 2 decades. Although vascular applications have been robust and steadily improving for many years, the utility of MRI for clinical cardiac imaging has been limited. However, recent advances in hardware technology and pulse sequence design have led to substantial improvements in image quality, while reducing scan times to clinically reasonable durations. Pulse sequences using electrocardiographic gating and k-space segmentation have made it possible to obtain high-contrast, high-resolution images of the beating heart within single breath-holds. These images in turn have provided unprecedented visualization of myocardial morphology and function. Because of these developments, cardiac MRI (CMR) has made rapid and dramatic inroads into the clinical arena. Currently, the primary limitations to routine clinical application are hardware availability, clinical acceptance, politics, examination cost, and not least of all physician education. As these limitations are overcome or made more manageable, the clinical use of CMR will grow, potentially without bound. Combined with steady hardware development and an ever-growing armamentarium of pulse sequences, MRI may ultimately become the modality of choice for cardiac imaging. Because cardiac imaging is relatively unknown territory for most radiologists and because the high-end equipment has until now been sparsely available, CMR has been largely limited to major medical centers. However, if sufficient interest is present and resources are appropriately allocated, CMR can be successfully implemented in community imaging practices.

Key Words: Cardiac MRI service

J Am Coll Radiol 2005;2:740-748. Copyright © 2005 American College of Radiology

INTRODUCTION

Over the past few years, the landscape of noninvasive cardiovascular imaging has changed dramatically. Several recent technological advances have made magnetic resonance imaging (MRI) and computed tomography (CT) clinically relevant modalities [1–7]. Magnetic resonance imaging in particular has become a robust and powerful tool in the clinical assessment of the heart, aorta, and great vessels and will serve as the focal point of this article. It is rapidly gaining acceptance in the medical community and is certain to witness considerable clinical growth over the foreseeable future.

This article reviews the cardiovascular applications of MRI and offers suggestions for implementing a cardiac MRI (CMR) service in the community setting. Over the past 12 months, our imaging department has developed a CMR program, essentially from scratch, and our experience is reviewed. Although we have witnessed early successes relating primarily to referral patterns and physician acceptance, the program is fledgling and continues to require nurturing through physician education, scanning and interpreting efficiency, and the continued improvement and refinement of our techniques.

The majority of this article focuses on the cardiac component of cardiovascular MRI. Although vascular imaging with both CT and MRI is also garnering significant clinical attention, most imaging groups already have a handle on this technology, have an established referral pattern, and are presently capable of performing and interpreting diagnostic quality examinations. In general, this is not the case for MRI and CT imaging of the heart.

NONINVASIVE CARDIAC IMAGING

To better appreciate the role of MRI, it is instructive at the outset to review briefly the strengths and weaknesses of echocardiography and nuclear cardiology, the current mainstays of noninvasive cardiac imaging. Both modalities are widely available and have proven clinical utility. Echocardiography is safe, relatively inexpensive, and portable, and it provides real-time assessment of cardiac contractile function, valve morphology and function, flow-

[a]Rhode Island Hospital, Providence, RI.

[b]Brown Medical School, Providence, RI.

Corresponding author and reprints: Michael Atalay, MD, PhD, Rhode Island Hospital, 593 Eddy Street, Providence, RI 02903; e-mail: matalay@lifespan.org.

0091-2182/05/$30.00 • DOI 10.1016/j.jacr.2005.02.002

related physiology (via Doppler techniques), and anatomy. Moreover, it is usually operated under the auspices of clinical cardiologists who are motivated by ease of access, extensive training in the modality, and financial incentive. For these reasons, echocardiography is cardiac imaging's workhorse. Virtually all patients with known or suspected cardiac disease will have transthoracic echocardiograms for the assessment of morphology and function. Although most radiologists are not well-versed in the nuances of echocardiography, most are familiar with the strengths and weaknesses of ultrasound imaging as a modality. Chief limitations include confined and occasionally poor acoustic windows (particularly around thoracic structures), limited field of view, and limited tissue contrast. Also, although 3-dimensional techniques are available, it is generally used as a 2-dimensional imaging modality.

Nuclear imaging techniques conducted during rest and stress states are routinely used to identify myocardial perfusion abnormalities associated with coronary heart disease. Perfusion defects seen on stress images that "fill in" at rest are believed to represent areas of ischemia or decreased coronary flow reserve. Perfusion defects that are unchanged between the two physiologic states—so-called fixed defects—usually identify areas of infarction. Contractile information is also obtained. Nuclear techniques have limited spatial resolution, use ionizing radiation, and may be hampered by soft-tissue attenuation.

Table 1. Indications for cardiac magnetic resonance imaging

- Myocardial viability
- Global and regional ventricular function
- Ventricular mass, cavity volumes, and myocardial morphology
- Pericardial diseases, such as constrictive pericarditis or hematoma
- Congenital heart disease before or after surgical repair
- Heart muscle diseases, including infiltrative processes and those involving the right ventricle such as arrhythmogenic right ventricular dysplasia
- Cardiac and extracardiac masses
- Valvular heart disease
- Bypass graft patency
- Presence and course of anomalous coronary arteries
- Pulmonary vein mapping before and after radiofrequency ablation for atrial fibrillation
- Diseases of the aorta, such as dissection, aneurysm, and coarctation
- Flow through large vessels and across valves (quantitative)

THE EMERGENCE OF MRI FOR CLINICAL CARDIAC IMAGING

Magnetic resonance imaging of the heart has been performed on a limited clinical basis since the early 1980s. Until recently, routine clinical application was largely hindered by the inability to freeze cardiac motion, poor gating methods, long scan times, and low contrast between blood pool and myocardium. Because of significant developments in hardware technology and pulse sequence design, MRI has emerged as a reliable method for imaging cardiac anatomy and function [1–7]. There are currently several widely accepted indications for CMR (Table 1).

Despite the wide-ranging routine indications and the frequent use of MRI for problem solving, perhaps the greatest potential of the modality, and strongest motivation for its continued development, is in the evaluation of coronary heart disease. On the basis of its prevalence, morbidity and mortality, and associated enormous health care costs, coronary heart disease may well be regarded as the bane of Western civilization [8]. Magnetic resonance imaging boasts many innovations that make it well suited to study this disease. Already, MRI is widely regarded as the gold standard for the assessment of global and regional myocardial contractile function as well as myocardial viability (discussed below). One notable current weakness of MRI in the assessment of coronary heart disease remains robust coronary angiography, a role that may be better addressed in the immediate future by CT. The imaging of perfusion and coronary flow reserve also continues to be work in progress for MRI. Reliable data on pharmacologic stress perfusion methods are limited, but current CMR techniques may be comparable in accuracy with nuclear methods [9–11].

Magnetic resonance imaging is a safe imaging technology [12] that has high spatial resolution (approximately 40 to 60 times that of nuclear cardiology), high temporal resolution (approximately 40 to 80 ms), and superior tissue contrast. Unlike echocardiography and nuclear cardiology, MRI is not significantly hampered by patient habitus. Although field of view, signal-to-noise ratio, and resolution may be affected on MRI, issues such as soft-tissue attenuation and poor acoustic windows do not arise. Cardiac MRI has the usual relative and absolute contraindications of general MRI and may be substantially limited by cardiac arrhythmia or the inability of subjects to perform breath-holds. In general, these limitations can be adequately addressed and diagnostic studies obtained.