Fast and Furious: The New Era of Rapid Imaging
Fast Cardiovascular Imaging, A Clinical Perspective

Frandics P. Chan, M.D. Ph.D.

Department of Radiology, Stanford University Medical Center

According to the American Heart Association, in the year 2006, there were more than 81 million Americans who suffered from cardiovascular disease of all forms. One in 17 Americans had coronary artery disease, and half of them had experienced myocardial infarction or heart attach. Despite the high prevalence of cardiovascular disease and decades of research and development of cardiovascular MRI techniques, cardiovascular imaging constitute only a small portion of all MRI studies in most clinical practice. Instead, imaging for neural and skeletomuscular indications dominate.

There are a number of reasons for this bias. Cardiovascular studies, especially when the heart is involved, are notoriously lengthy. The cardiac scan planes can be difficult to prescribe and require a good understanding of the cardiac anatomy by the operator at the scanner. For vascular studies, the size and location of region of interest can vary greatly, which require a flexible deployment of imaging coils. The specialized cardiovascular MRI sequences are more complex to prescribe and to optimize, requiring the operator to undergo special training. The needs for breath-holds and regular heart beats assume that the patients are in good physical conditions and mentally cooperative. This is often not the case for very sick patients or young children. Breath-holding also prolong the study, and in some cases, and it might even alter the cardiovascular physiology being studied.

The number of images produced per cardiovascular study can be in the thousands, straining the capacity of the electronic picture archive communication system (PACS). Additional technologist or physician time is spent on image post-processing to produce 3D rendered images for diagnostic interpretation and for illustration of pathology. In studies that evaluate heart functions, ventricular volumes and blood flows must be measured, validated for consistency, and compared in serial studies. All these activities consumes time and resources in a busy clinical practice and lowers revenue generated per study. Facing these difficulties, it is no surprise that there are few qualified imaging physicians or technologists to perform these studies.

Technical improvements in the following area may ameliorate some of these issues:

(A) <u>Increase data acquisition per breath-hold.</u> The goal is to shorten each breath-hold time or to reduce the number of breath-holds, and thereby shortening the overall study time and improving patient's comfort. The means to achieve this acceleration has been demonstrated and implemented with parallel imaging, such as SENSE, GRAPPA, and k-t BLAST. For cardiac applications, the number of breath-holds for multi-slice acquisition can be substantially reduced, without sacrificing temporal resolution. For vascular applications, the spatial resolution or coverage of a 3D MRA can be increased. Alternatively, the saving in scan time can be used to run serial, time-resolved MRA.

(B) Eliminate the need for breath-hold. The goal is to remove the need for patient cooperation. Many respiratory control techniques have been explored. Currently, in most clinical implementation of balanced-ssfp coronary MRA, respiratory motion is controlled by navigator echo coupled with respiratory triggering. More sophisticated respiratory control methods exist but had variable successes depending on the respiratory pattern and anatomy of the patient.

(C) Move anatomical and physiological analysis to post-processing. The goal is acquire a cardiac-gated, 4D block of anatomic or flow data that roughly contain the pathology. The exact prescription of the block is not important during the scan. The 4D data are examined by the imaging physician after the study has completed. This workflow eliminates the need for highly skilled technologist at the scanner in a manner similar to a cardiac CTA study today.

(D) Improve post-processing tool for rapid extraction of physiological data. The goal is to assist the evaluation and data quantification of the large 4D data set. Very efficient 3D post-processing workstations already exist in the clinical realm. This needs to be expanded to handle time-varying scalar field for anatomy and vector field for flow information. Efficient 4D segmentation algorithm and phase-contrast eddy-current correction algorithm must be incorporated in the image post-processing workstation.

With an aging population in developed countries, cardiovascular MRI study will be needed by an increasing number of patients. The current imaging protocol and post-processing paradigm are time-consuming and labor intensive. They are ill-suited for the challenge. Technology must be developed and implemented not only to improve the rate of image acquisition, but also to improve the efficiency of work flow and patient care delivery.