Present Status and Future of MR in Medicine

Thomas J. Brady, M.D.
President-Elect, International Society of Magnetic Resonance in Medicine
Director, MGH-NMR Center
Professor, Department of Radiology
Massachusetts General Hospital and Harvard Medical School

Magnetic resonance (MR) has experienced a tremendous growth in both number and types of systems and in their medical applications. New MR systems provide both high spatial resolution (<100 μm) and ultra fast image acquisition (<100 msec). These advances will facilitate accurate quantitative imaging and, more importantly, underpin the development of functional MR imaging. High speed MRI can be used to increase patient throughput, evaluate physiological processes in real time or provide the time to assess multiple NMR parameters (perfusion, diffusion, etc.) in a single exam. In addition, fast image acquisition will enable the evaluation of uncooperative patients and reduce or eliminate the need for sedation. High resolution imaging will expand the clinical indications as well as continue the explosive growth of MR microscopy in bioscience. In concert with these technical developments, novel magnetopharmaceuticals, including blood pool, perfuion and target specific agents, will lead to enhanced medical as well as nonmedical applications.

All aspects of clinical MR will benefit from the enhanced speed, resolution and novel magnetopharmaceuticals. MR angiography will become the method of choice for vascular imaging as both spatial (1024 x 1024 matrix) and contrast (blood pool agents) resolution improve. Continued improvements in MR angiography will replace conventional angiographic studies for most clinical indications including the assessment of the pulmonary vasculature and coronary arteries. By the year 2000, cardiac MR will become the preferred diagnostic imaging modality for evaluating patients with suspected heart disease. An integrated approach will be implemented that includes high resolution anatomic imaging, assessment of myocardial and valvular performance and the evaluation of coronary vessels for both the presence of stenosis (modified MRA techniques) and the physiological significance of a stenotic lesion(pharmacological stress test to assess myocardial perfusion). Real time imaging will facilitate the studies of function and perfusion and expand the patient population to include patients with cardiac arrhythmias.

Dedicated MR imaging systems for localized examinations (e.g. knee and breast), will provide detail for many clinical applications. High resolution 3-D breast imaging, in concert with nonspecific or target specific agents will both enhance the detection of breast cancer and provide better information to guide therapy. MR systems with improvements in speed will be developed that allow interventional studies including real time temperature mapping to assess the effects of laser surgery. The development of "open" magnets will facilitate MR guided procedures in general. Scan parameters (TR, TE, resolution, etc), will by dynamically modified to produce MR images at fluoroscopy rates. Ultrafast imaging, alone or with contrast agents, will drive the development of

whole body MR imaging. Parallel improvements will be required in data handling and image display. Images derived from functional date (e.g. myocardial strain, myocardial architecture, blood volume) will play a greater role in diagnosis.

MR imaging techniques will enable the accurate assessment of tissue and organ physiology using both endogenous and exogenous contrast strategies. Real time imaging will facilitate the global and regional quantitation of physiological parameters. Assessment of brain hemodynamics has been demonstrated using serial imaging during the first pass transit of MR contrast agents. Post processing of these data generates high resolution synthetic maps of blood volume that can be used to determine disease activity, optimal biopsy site and assess therapeutic response. These data compare favorably with positron emission tomography (PET) studies of blood volume (^{11}CO) and metabolism (^{18}FDG). Real time diffusion and perfusion imaging will enable the detection of stroke (acute brain attack) within 2 hours of onset and provide critical information in the management of these patients. This approach can detect changes in cerebral blood volume induced during task activation paradigms such as photic stimulation. Even more exciting is the use of non contrast approaches that demonstrates real time changes in MR signal in response to various task activations. The blood oxygen level dependent (BOLD) contrast approach, which exploits the difference between oxy- and deoxyhemoglobin concentration in the capillary and venous blood, has become an important tool in cognitive neuroscience. The BOLD technique will also be used to localize language and sensorimotor areas in presurgical planning of patients.

The role of magnetopharmaceuticals will continue to expand. Oral agents will made MR competitive with body CT in extrahepatic imaging of the abdomen. MR receptor and antibody imaging will be a major development that combines the functionality of scintigraphy with the high spatial resolution of MR imaging. Perquisites for target specific contrast agents include: 1) potent magnetic label; 2) ability to cross the capillary endothelium; and 3) easy, stable and non destrcutive linkage with various biomolecules. Monocrystalline iron oxide nanoparticles (MION), a recently developed superparamagnetic preparation, meets these requirements and has been successfully used *in vivo* to detect pathological processes such as myocardial infarction (MION-antimyosin), inflammation (MION-IgG) as well as assessment of functional activity such as axonal transport (MION-wheat germ agglutinin).

The future of MR imaging is very bright. The ability of MR imaging to provide functional as well as biochemical information will greatly enhance basic research and clinical applications. MR imaging will not only become the cornerstone of Radiology but will also significantly change the focus of biomedical imaging.