

The amount of available signal in conventional magnetic resonance imaging (MRI) is inextricably tied to the static magnetic field strength (B_0) of the imaging system. Until recently, most clinical MRI scanners operated at field strengths at or below 1.5 Tesla. However, due in part to improvements in magnet design and shielding, which ease siting requirements, 3 Tesla clinical scanners are now widely available and there is a push for even higher field whole body scanners (7-9Tesla) throughout the industry.

The drive towards high-field MRI is fueled by the benefits of potentially higher signal-to-noise ratios, contrast-to-noise ratios, and spectral resolution. In many cases, these benefits will facilitate higher spatial and/or temporal resolution than previously possible with MRI at lower fields. There are, however, technological, physical and safety limitations inhibiting the full realization of these benefits at high-field. Technology issues include homogeneity of the static and radiofrequency magnetic fields, higher gradient coil performance and linearity, and the design of robust radiofrequency array coils for signal reception. At high-field, physics concerns include changes in relaxation kinetics, increased susceptibility effects and other changes in contrast mechanisms. Safety limitations include higher power radiofrequency pulses and the potential for tissue heating or coil burns, stimulation effects from stronger, faster switching gradients and moving within a higher magnetic field and, most prominently, the potential dangers associated with the main magnetic field, such as ferromagnetic projectiles in the scan room and effects on implanted medical devices, many of which have not been evaluated at fields above 1.5 Tesla.

Ultimately, the design of protocols and acquisition methods that account for these limitation will need to be pursued in order to reap the benefits of high-field MRI without compromising patient safety. Many MR imaging techniques have already seen demonstrable improvement at higher fields and have driven the development and distribution of high-field systems. Techniques in functional magnetic resonance imaging that rely on blood-oxygen level dependent contrast mechanisms, techniques in angiography and techniques in dynamic susceptibility contrast perfusion imaging all benefit from the effects of higher fields on local susceptibility contrast. Proton MR spectroscopy methods for brain and body imaging benefit from the higher spectral resolution of high field as do multi-nuclear techniques. Changes in relaxation kinetics provide enhanced contrast in angiography techniques and arterial spin labeling techniques.

This course will review the technology and physics behind high-field systems (3-9 Tesla) with an emphasis on the commercially available and widespread 3 Tesla systems. Major applications of high-field MRI will be addressed with an eye on the future. Aspects of safety in high-field MRI will also be covered, paying particular attention to how safety may influence the development and implementation of patient protocols.

Educational Objectives:

1. Understand relevant technology, physics and techniques behind high-field MRI.
2. Understand benefits and limitations of high-field MRI.
3. Understand safety concerns associated with high-field MRI systems.
4. Develop an awareness of some of the most relevant applications of high-field technology for MR imaging.