What Life Scientists Should Know About Molecular Imaging

MR Fundamentals for Life Scientists

Other Practical Considerations

T. Dixon
Radiology and Imaging Science, Emory University, Atlanta, Georgia, USA

Learning Objectives:

- Learn relation of magnetic resonance imaging to Relaxation Field Strength Susceptibility
- Learn about MRI Facility Concerns
- MRI Safety

Relaxation: T1, T2, and T2* relaxation dominate image contrast and affect temporal resolution and even spatial resolution. Resolving adjacent voxels requires putting 1/2 revolution of phase between them in ~T2, which is hard to do if gradients are weak or T2 short. In standard spin-warp imaging, T1/2 <TR <T1. Halving T1 delivers the first image in half the time and speeds up a dynamic series 2 fold. However, because the method can work on ~TR/TE slices at once, cutting T1and TR in half does not change the number of images made per minute.

B0 Effects: Doubling B0 would quadruple signal by doubling flux and halving the precession period but it also raises noise. S/N increases by factors of 2^(7/4) in small, insulating liquid samples and 2 for large, slightly conductive, common MRI samples. High B0 gives no S/N advantage for hyperpolarized He3, C13, or Xe129. Doubling B0 can raise subject heating, SAR. If an RF pulse does the same thing in the same time, the higher field pulse deposits 4x the energy. If T2* shortening with B0 limits the high B0 pulse to half the duration, the higher field pulse deposits 8x the energy.

Susceptibility: Susceptibility complicates B0 maps greatly confounding some methods and enabling others. Diamagnetic substances, i. e. having negative susceptibility e. g. water, repel magnetic lines of force thus decreasing the field some places near a diamagnetic object and increasing it elsewhere. The effect range is about the size of the object. The complicated, shape-dependent resonant frequency change this makes is comparable to the resonant frequency difference between two lines in proton NMR. This is why frequency-based selective saturation and selective excitation methods are not robust. In some regions, information is missing and cannot be recovered. Exciting everything and keeping track of phase can make selective imaging, e. g. no fat, robust (1) and with special image processing, can even provide more information from images (2,3). The susceptibility difference between oxy-and deoxy-hemoglobin led to the first MRI method to show brain function (4).

Facility Design: Facility design has grown simpler because self shielded magnets have compact fields and monitors that are unaffected by magnetic fields replaced cathode ray tubes. Room lighting was difficult because fluorescent lights made images noisy and stray fields made tungsten AC filaments vibrate and fail by fatigue, requiring trained personnel and a nonmagnetic ladder for replacement. LED's outlast imagers.

Safety: Whole body MR has hazards from energy stored in the magnet and from contrast-agent toxicity. Ear protection is needed because of rapid magnetic field gradient changes that rattle any metal in the

magnet, even causing painful, direct stimulation in the body. A whole-body imager uses an RF transmitter 10x as powerful as a microwave oven. It is important to know where this power goes. FDA guidelines had to be developed before there were any easy ways to determine subject heating (5,6). Scientifically the safety problem is the same as monitoring thermal ablation or adjuvant heating during radio- or chemo-therapy.

References:

1. Jingfei Ma. Breath-Hold Water and Fat Imaging Using a Dual-Echo Two-Point Dixon Technique With an Efficient and Robust Phase-Correction Algorithm. Magn Reson Med 52:415-419; 2004.
2. Dixon WT, Blezek DJ, Lowery LA, Meyer DE, Kulkarni AM, Bales BC, Petko DL, Foo TK. Estimating amounts of iron oxide from gradient echo images. Magn Reson Med.61:1132-6; 2009.
3. S Mittal, Z Wu, J Neelavalli, EM Haacke. Susceptibility-Weighted Imaging: Technical Aspects and Clinical Applications, Part 2. AJNR 30:232-252; 2009.
4. S Ogawa, TM Lee, AR Kay, DW Tank. Brain magnetic resonance imaging with contrast dependent on blood oxygenation. Proc Natl Acad Sci USA 87:9868-72;1990.
5. WA Grissom, V Rieke, AB Holbrook, Y Medan, M Lustig, J Santos, MV McConnell, K Butts Pauly. Hybrid referenceless and multibaseline subtraction MR thermometry for monitoring thermal therapies in moving organs. Med Phys 37:5014-26;2010.
6. Sacolick LI, Wiesinger F, Hancu I, Vogel MW. B1 Mapping by Bloch-Siegert Shift. Magn Reson Med 63:1315-22;2010.

Disclosure of author financial interest or relationships: W.T. Dixon, None.