BMB/BE 581
Techniques of Magnetic Resonance Imaging

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Office Hours: TBD
1 Founders Building (MRI Learning Center)

Curriculum Summary

Detailed introduction to the physics and engineering of magnetic resonance imaging and its applications in medical imaging. Covered are: Bloch equations, spatial encoding principles, Fourier analysis, spin relaxation, imaging pulse sequences and pulse design, contrast mechanisms, chemical shift imaging, induced magnetism, flow encoding, diffusion and perfusion, high-field MRI and a discussion of the most relevant clinical applications.

Weekdays and time: **Mondays and Wednesday, 5:00 – 6:30pm**
Location: **Large Conference Room, MRI Learning Center, 1 Founders**

Grading: 25% Homework, 25% Midterm, 35% Final, 15% Student Presentations

Textbook: Although we will not strictly follow a text, you may find the following references to be useful:

1. ***Principles of Magnetic Resonance Imaging***
   Nishimura, 2010, www.lulu.com (look for the softcover)
2. ***Magnetic Resonance Imaging: Physical Principles and Sequence Design***
   Haacke, et al, Wiley, 1999
3. ***Handbook of MRI Pulse Sequences***
   Bernstein, et al, Elsevier, 2004
4. Useful link: ***The Basics of MRI***
   Hornak <http://www.cis.rit.edu/htbooks/mri/>

Schedule

Date	Topic	Description
Jan. 16 Wed (Wehrli)	Basics of NMR	Nuclear spin, magnetic moment, gyromagnetic ratio, nuclear precession, Larmor equation, bulk magnetization excitation and detection
Jan. 21 Mon	**No class (MLK Day)**	
Jan. 23 Wed (Song)	MR Hardware	Magnet, gradient system, siting issues, eddy currents/ compensation/shielded gradients; Principle of signal detection, resonant circuits, RF system: transmit/receive, RF coils: design criteria, coil loading, quality factor, matching and tuning
Jan. 28 Mon (Wehrli)	Bloch Equations and Signal Detection	Rotating frame, solutions for various initial conditions, time & frequency domain, Fourier transform
Jan. 30 Wed (Wehrli)	Fundamentals of spin relaxation: T1, T2, T1ρ	Correlation and power spectral density function, dipole-dipole and other relaxation mechanisms, chemical exchange
Feb. 4 Mon (Song)	RF Pulses and Excitation (Nishimura, Ch. 6)	Amplitude and frequency modulation schemes, sinc and hard pulses, adiabatic inversion, nonlinearity problem
Feb. 6 Wed (Wehrli)	Signal and Contrast	Image signal intensity and contrast in MRI, role of relaxation times, techniques for measuring relaxation times (T1, T2, T1ρ), coherence pathways
Feb. 11 Mon (Wehrli)	Spatial Encoding and K-space	Gradient fields, gradient rephasing, k-space concept and properties, imaging equation, sampling
Feb. 13 Wed (Witschey)	Fourier Imaging Techniques I	Rectilinear sampling: spin warp imaging, gradient and spin echo embodiments, 3D spin-warp imaging, signal and contrast
Feb. 18 Mon (Song)	Image Reconstruction	Fundamentals of Fourier transform, sampling theorem, field of view, resolution, modulation transfer and point spread function, partial Fourier
Feb. 20 Wed (Witschey)	Fourier Imaging Techniques II	Introduction to echo-train imaging: EPI and RARE, contrast implications, point-spread function, artifacts
Feb. 25 Mon (Tisdall)	SNR in MRI (Nishimura, Ch. 7.5)	Properties of noise: Gaussian, Rayleigh and Rician, measurement of SNR, dependence on scan parameters
Feb. 27 Wed	**Mid-Term Exam**	
Mar. 4 Mon	**Spring Break**	
Mar. 6 Wed	**Spring Break**	
Mar. 11 Mon (Witschey)	Advanced Imaging Techniques I	Imaging with multiple receive coils, reconstruction issues, SNR, parallel imaging: SENSE and SMASH, image reconstruction artifacts

Mar. 13 Wed (Song)	Advanced Imaging Techniques II	Fat/water separation, rapid imaging techniques, keyhole technique, imaging of solids, imaging near metals, imaging of hyperpolarized spins, temperature mapping
Mar. 18 Mon (Langham)	Flow Imaging Techniques (Nishimura, Ch. 10)	Time of flight and phase effects, gradient moment nulling, flow encoding methods, angiographic imaging techniques, vascular imaging and flow quantification
Mar. 20 Wed (Witschey)	Cardiovascular MRI	Dark/bright blood imaging, cardiac gating, cine imaging techniques, tagging methods, cardiac T1 mapping, tissue characterization using modified Look-Locker
Mar. 25 Mon (Wehrli)	Magnetic Susceptibility	Fundamentals of induced magnetism, image artifacts, applications: bone, iron, measurement of hemoglobin saturation, Quantitative Susceptibility Mapping
Mar. 27 Wed (Wehrli)	Spectroscopic Imaging	Chemical shift and spin-spin coupling, 2-component chemical shift selective imaging: saturation and selective excitation, echo offset techniques, PRESS, STEAM, spectroscopic imaging, conventional phase-encoding methods, high-speed EPI
Apr. 1 Mon (Detre)	Perfusion and Functional MRI	Physics of microcirculation, first-pass contrast methods, diffusible tracer methods (ASL), clinical applications; BOLD, fMRI acquisition techniques, processing of fMRI data, design of fMRI paradigms
Apr. 3 Wed (Wehrli)	Diffusion MRI	Pulsed gradient diffusion experiment, diffusion tensor imaging, fiber tracking, diffusion in background gradients, Q-space imaging
Apr. 8 Mon (Song)	Alternative Image Acquisition Schemes	Radial scanning (UTE/ZTE), spiral, regridding and reconstruction, artifacts, PROPELLER/BLADE
Apr. 10 Wed (Rajapakse)	Other Reconstruction Strategies	Iterative reconstruction, regularized reconstruction, compressed sensing
Apr. 15 Mon (Song)	Steady State Imaging	Steady-state conditions and signal formation, balanced steady-state free precession, image contrast, transient period, clinical applications
Apr. 17 Wed (Tisdall)	Motion Reduction Techniques	K-space analysis of motion, respiratory gating, navigator echoes, retrospective motion correction, prospective compensation
Apr. 22 Mon (Song)	Imaging Artifacts and Compensation	Common artifacts (aliasing, ghosting, zipper, N/2, flow, etc.) and means for their reduction
Apr. 24 Wed (Song)	MR Safety	SAR, dB/dt, gadolinium CA, quenching, flying objects, pregnancy, implantable devices, RF coils and cables, imaging at high fields (>3T), etc.
Apr. 29 Mon	**Student Presentations**	
May 1 Wed	**Student Presentations**	
May 6-May 14	**Final Exam**	

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Homework Schedule 2017
No late homework will be accepted!

Assignment #	Topic	Distribution Date	Due Date
Homework #1	Bloch equations, Relaxation, Signal and Contrast	1/23	2/6
Homework #2	Imaging pulse sequences, K-space, Reconstruction, RF pulses, Spatial encoding, SNR	2/6	2/25
Homework #3	Fourier techniques, Advanced imaging techniques	2/25	3/20
Homework #4	Flow, Susceptibility, Cardiovascular techniques	3/20	4/3
Homework #5	Steady state, Motion, Artifacts, Alternative imaging techniques	4/3	4/24