MRI & Spectroscopy - Provisional Lecture Synopses

Notes
Topics are covered at a level appropriate for an introductory course, so some include greater detail than others. The final lecture ordering may be subject to change.

Lecture 1: Basis of NMR

Meaning of “NMR”; basic properties of the hydrogen nucleus (“proton”); precession in a magnetic field (classical picture); Larmor equation; energy levels in a magnetic field; size of bulk magnetisation; effects of RF (“B1”) fields; Rotating frame, free precession and signals (FIDs).

Lecture 2: Relaxation Parameters and Spin Echoes

Obtaining transverse magnetisation (review); nutation and 90-degree pulses; obtaining NMR signal; quadrature detection and complex nature of NMR signals; brief review of Fourier transforms; effect of FT on single decaying sinusoid and on superposition of FIDs at several frequencies; relation of decay rate to line width; transverse relaxation - overview of underlying mechanism and consequences for NMR signals; longitudinal relaxation; the Bloch equations, measuring T1 by inversion recovery method (and by SR?); spin echoes, measuring T2.

Lecture 3: Magnetic Field Gradients, Slice selection and Frequency Encoding

What are magnetic field gradients - Gx = dBz/dx etc.; principle of slice selection; importance of RF pulse profile - rectangular, sinc, gauss. Why sinc pulses do not give rectangular profiles. Brief mention of optimisation schemes - SLR pulses etc. Gradients and 1-d profiles - frequency encoding; mention of projection-reconstruction imaging (not in detail); introduction to sequence timing diagrams

Lecture 4: Basic Imaging Sequences: Spin-echo and Gradient echo

Review spin-echo and refocusing of T2* effects; timing diagram for SE sequence; requirements of gradient refocus lobes for slice-select and read directions; mathematical form of partial saturation effects; Ernst angle; multi-echo SE sequence; magnitude and phase reconstructions; slice-thickness and profile; calculating gradients required for specific fields-of-view

Lecture 5: 2-D FT Imaging, k-space

Magnetic field gradients and 1-d profiles (review); mathematical form of NMR signal with continuous and pulsed gradients; phase-encoding; 2d-gradient-echo sequence; k-space; relation of kspace and real space; strategies for scanning k-space; multislice imaging

Lecture 6: Hardware: RF Requirements and RF Coils

Overview; need for screened rooms; basic coil configurations - Tx/Rx and Rx only; transmit-receive switches and decoupling networks; coil designs - body, head, spine, surface, phased arrays; LP and CP; basic resonant circuit theory; matching the coil to 50Ω; measuring loaded and unloaded Q; eddy-current heating and SAR effects; phase-sensitive detection

Lecture 7: Safety Considerations

Physical effects - cryogens, projectiles, acoustic noise; Biological effects - magnetic field, gradient switching, RF heating; IEC guidelines; system monitoring feature

Lecture 8: Hardware - Magnets, Gradients and Eddy currents

Overview of MRI system; magnets - types, field strength, homogeneity, stability, shimming, fringe field and shielding; gradient coils - geometry, amplitudes and rise-times; eddy-currents; preemphasis; shielded gradient sets

Lecture 9: Image Contrast, Resolution and Signal-to-noise

Image contrast - proton density; TE and T2-weighting; TR and T1-weighting; inversion-recovery sequences; examples of sequence parameters used clinically; Factors affecting SNR in MRI - gamma, B0, spin density, temperature, coil design, pixel size, no of acquisitions, bandwidth, sources of noise; signal sampling; gradient strength and resolution; line width broadening; chemical shift artefact

Lecture 10: MRI in Practice

Multislice vs. 3d acquisition; fast spin-echo; respiratory motion and exchanging read/phase directions; gating; use of oblique slices; saturation slabs; fat sat; half-Fourier and oversampling; examples of sequences used for specific cases with rationale; contrast agents; patient monitoring; QA

Lecture 11: MRI in Radiotherapy Planning
Advantages of MRI; challenges of MRI; MR-CT fusion; RMH experience; MR-linacs; MRI for CyberKnife; MRI of markers; assessment of motion; functional MRI

Lecture 12: K-space Trajectories

Lecture 13: Quantitative Imaging

Lecture 14: Acceleration of MR Sequences

Lecture 15: Diffusion MRI

Lecture 16: Introduction to *in vivo* MR Spectroscopy

A biochemical rather than anatomical tool; nuclei of biological interest (relative sensitivity, frequency, chemical shift range); example metabolites and concentrations; origin of chemical shift; nuclei with I > 1/2; importance of localisation; surface coils for MRS - advantages and problems; shimming; choice of acquisition parameters; current status of MRS; examples

Lecture 17: MRS Acquisition and Analysis

Lecture 18: MRI for Clinical Drug Development

Introduction to drug development; imaging for drug development; MR case studies; challenges of multicentre imaging; developing new techniques; future role of MRI

Lecture 19: Flow and MR Angiography

Time-of-flight effects; Phase effects; uniform and pulsatile flow; flow-compensated sequences; MRA methods - TOF, phase-contrast, quantitative flow measurements; use of contrast-agents; current status; flow vs. perfusion

Lecture 20: Functional Imaging Methods

Relationship between flow, perfusion and diffusion; perfusion using contrast agents; introduction to arterial spin-tagging methods; diffusion MRI; introduction to functional MRI.

Lecture 21: MRI from a Clinical Perspective

A summary of the rationale for the use of MRI in the clinic, together with examples of sequences involving different contrast mechanisms.