MR Pulse Sequences

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Disclosure

• No conflicts of interest
Outline

- Spin echo
- Inversion recovery
- Gradient echo
- Echo planar
- K-space trajectories

Spin Echo

- Uses 90° and 180° flip angles
- Spin density contrast: short TE, long TR
- T1 contrast: short TE, short TR
- T2 contrast: long TE, long TR
- Rephases effects from $B_0$ inhomogeneity, chemical shift, and magnetic susceptibility
- Scan time = TR x $N_p$ x NSA

TR: Repetition time
$N_p$: # phase encodes
NSA: # signal averages = NEX: # excitations
Spin Echo

- RF
- Signal
- ADC
- $G_{\text{slice}}$
- $G_{\text{freq}}$
- $G_{\text{phase}}$
- $90^\circ$
- $180^\circ$
- TE
- TR

Filling K-space

- The signal from the echo is sampled; the values are placed in k-space.
Image space k-space

Single Slice Spin Echo

1 Slice
RF
Signal
ADC
G_slice
G_freq
G_phase

TE

TR
Multi-Slice Spin Echo

- RF
- Signal
- ADC
- Gslice
- Gfreq
- Gphase

Slice 1

Slice 2

Slice 3

TE

TE

TE

TR

Multi-Echo Spin Echo

- Multiple images, each with different contrast
- Multiple 180° pulses, to create multiple echoes
- Each echo is used to form a separate image
- Each image will have different contrast ranging from spin density to strong T2, depending on TE for that echo
Multi-Echo Spin Echo

- Multiple 180° pulses to create multiple echos
- All echos used to create single image
- Scan time decreased by echo train length
- T1 and T2 weighting
- Scan Time = TR x NP x NSA / ETL
Turbo Spin Echo

Echo Train Length (ETL) = 4

ETL = 4
is 4 Times Faster!

256 TR
Periods

64 TR
Periods

SE

FSE
Inversion Recovery

- Can be used to produce strong T1 weighted images
- Can be used to suppress fat, e.g. short TI inversion recovery (STIR)
  - Does not depend on $B_0$ inhomogeneity
- Can be used to suppress fluid, e.g. fluid-attenuated inversion recovery (FLAIR)
Gradient Echo

- Partial flip angle, no 180° refocusing pulse
- This allows very short TR
- Uses gradients to rephase echo
- Produces T1 or T2* contrast
- Scan time = TR x N_p x NSA
- Options include spoiled GE, steady-state GE
- Does not rephase effects of B_0 inhomogeneity, chemical shift, or magnetic susceptibility
Gradient Echo

Flip Angle - 90°

Direction of main magnetic field
Longitudinal Direction
Transverse (x,y) Plane
Flip Angle - $\alpha^\circ$

Direction of main magnetic field

Longitudinal Direction

Transverse (x,y) Plane

Gradient Echo (Spoiled / Incoherent)

- “Spoiling” is used to remove residual transverse magnetization at end of sequence, before next RF pulse
- Spoiling is accomplished by using extra gradient pulses, RF pulses, or both to completely dephase the spins
- E.g. Fast Low Angle Shot (FLASH); Spoiled Gradient Recalled Echo (SPGR); T1 Fast Field Echo (T1-FFE)
Gradient Echo – Spoiled / Incoherent

Gradient Echo (Steady-state / Coherent)

- Residual transverse magnetization at end of sequence is “rewound”
- This signal then combines coherently with new signal in the transverse plane, increasing overall signal
- E.g. Gradient Recalled Acquisition in the Steady State (GRASS); Gradient Recalled Echo (GRE); Fast Imaging with Steady-state Precession (FISP); Fast Field Echo (FFE)
Gradient Echo – Steady State / Coherent

Example: FISP
Echo Planar

- Method of ultrafast MR signal acquisition
- All of k-space can be acquired in a “single shot” by rapid gradient reversal and echo collection after a single set of RF pulses
- EPI is a fast readout mechanism; the excitation pulses produce the contrast, the signal is read with EPI
Echo Planar – Filling K-space

K-space Trajectories

- Cartesian
  - Linear
  - Centric
- Non-cartesian
  - Radial
  - Propeller
  - Spiral
Cartesian - Linear

Image contrast at center of k-space

Cartesian - Centric

1
2
3
4
5
6
7
8
9
Non-Cartesian – Spiral

Recommended Reading

- Breast MRI – Fundamentals and Technical Aspects. R.Edward Hendrick. 2010
- MRI From Picture to Proton. McRobbie, Moore, Graves, Prince. 2007
Thank You
Mayo Clinic Florida

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