MR Pulse Sequences

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Disclosure

• None
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 $\times$ N$p$ $\times$ 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° 180°

Filling K-space

- The signal from the echo is sampled; the values are placed in k-space.
Image space  \hspace{1cm} 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
- $G_{\text{slice}}$
- $G_{\text{freq}}$
- $G_{\text{phase}}$

Multi-Echo Spin Echo

- Multiple images, each with different contrast
- Multiple 180° pulses, to create multiple echos
- 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
Turbo (Fast) 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 N_P x NSA / ETL
Turbo Spin Echo

Echo Train Length (ETL) = 4

ETL = 4 is 4 Times Faster!

256 TR Periods

64 TR Periods
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)
Inversion Recovery - STIR

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°
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

- RF
- Signal
- ADC
- $G_{slice}$
- $G_{freq}$
- $G_{phase}$

E.g. FISP

Gradient Echo – Steady State / Coherent

- RF
- Signal
- ADC
- $G_{slice}$
- $G_{freq}$
- $G_{phase}$

E.g. True 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
Non-Cartesian - Radial

Non-Cartesian - Propeller
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
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