Basic Pulse Sequences

Lecture 20

Nov 9, 2005

Handbook of MR pulse sequence

- Gradient Echo and SNR
- Spin Echo and measurement of relaxation times

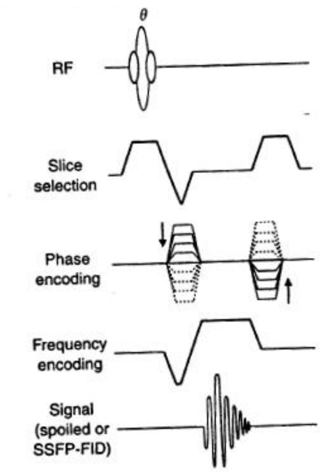
Final Projects

Gradient Echo (GRE)

- Used primarily for
  - fast imaging (e.g., vascular and cardiac imaging and acquisition that require breath holding)
  - Good contrast for angiographic pulse sequences
  - Provide susceptibility weighted images (why?)

- What forms the echo if there is no 180^o RF refocusing pulse

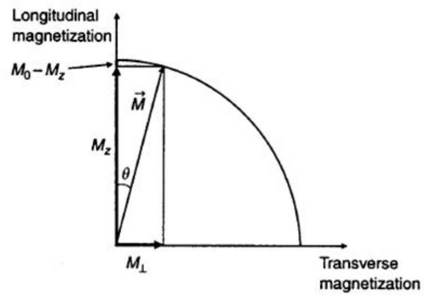
GRE



Why is GRE Fast

- Tip angle less than 90^0 leading to a less period of time for T1 recovery (short TR 2-50 ms possible)
- Low flip angles result in the longitudinal magnetization undisturbed while significant transverse magnetization is created (why?)

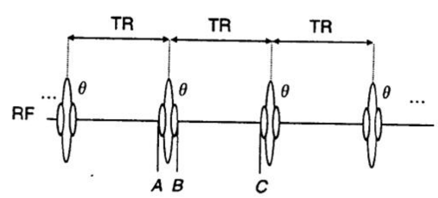
Response to a small flip angle



θ <<1 rad (57^0), $\sin \theta = \theta$, $\cos \theta = 1 – \sin \theta = \theta^2/2$

Response to a series of RF excitation pulses

- Steady state or dynamic equilibrium
- GRE can be classified by the response of the transverse magnetization
  - Spoiled: zero before each RF excitation pulse
  - Steady-state free precession (SSFP): a non-zero steady state before each RF excitation pulse



Spoiled GRE

- Produce images with T1 weighted contrast
- How can we achieve spoiling?
  - Chose a TR > 4T2 (not fast)
  - Use of gradient spoilers (spatially non-uniform producing strip patterns)
  - RF spoiling: phase cycle the RF excitation to a predetermined schedule (The received MR signal must be shifted by the added phase so the k-space data is consistent)

Steady State of the Longitudinal Magnetization for Spoiled Pulse Sequences

$M_{zB} = N_{zA} \cos\theta$

Between B and C . T1 relaxation occurs according to :

$M_{zC} = M_{zB} e^{-TR/T_1} + M_o (1 - e^{-TR/T_1}) = M_{zA} \cos\theta E_1 + M_0 (1 - E1)$

where $E_1 = e^{-TR/T1}$

At steady state $M_{zA} = M_{zC}$

Elimanating M_{zC}

$$\frac{MzA}{M0} = \frac{1 - E_1}{1 - \cos\theta E_1} \equiv f_{z,ss}$$

$f_{z,ss}$:dimensionless measure of the steady state longitudinal magnetization

Spoiled GRE signal

$$S_{spoil} = M_{zA} Sin\theta e^{-TE/T_2^*}$$
$$= \frac{M_0 \sin\theta(1-e^{-TR/T1})}{(1-\cos\theta e^{-TR/T_1})} e^{-TE/T_2^*}$$

Ernst angle (θ): The flip angle that maximizes the spoiled GRE signal

$$\theta_E = \cos^{-1}(E_1) = \cos^{-1}(e^{-TR/T_1})$$

HW 5 P1:

Derive θ_E

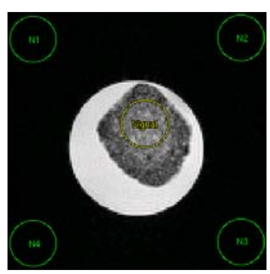
Plot the Ernst angle vs $e^{-TR/T1}$

Signal-to-Noise Ratio (SNR) Measurement

Saturation recovery with TE 7 ms, TR 50 - 6000 ms

$$\mathrm{SNR} = \frac{\mathrm{mean(Signal)}}{\mathrm{mean(std(Noise))}}$$

$$\mathrm{SNR} = \mathrm{SNR}_0 (1 - e^{-TR/T_1})$$



Signal	Noise				SNR
	N1	N2	N3	N4	
124	1.64	1.55	1.59	1.48	124/1.56 = 80