Lecture 6
Gradient Echo Based Techniques and Applications
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The Anatomy of Basic MR Pulses

**Magnetization Preparation Section**
- Chemical Shift Selective Saturation/Excitation
- Spatial Selective Saturation
- Magnetization Transfer (MT), CHESS water suppression
- Inversion Recovery (IR)

**Data Acquisition Section**
- Shot/Slab Selective Excitation
- Phase Encoding
  - Spatial locality (SE), Echo Planar Imaging (EPI), Single-shot FSE (HASTE)
  - Gradient Recalled Echo (GRE), Single-shot GRE (EPI)
- Diffusion Weighting (DWI/DTI) and Gradient Moment Nulling (GMN)
- Frequency Encoding
- Filling of K-space

**Magnetization Recovery Section**
- Spoiling
- Driven Equilibrium

Gradient Recalled Echo (GRE)

GRE versus SE

- No 180° refocusing RF pulse
  - De-phasing in the transverse plane due to chemical shift and B₀ inhomogeneity is NOT recovered.
  - T₂* weighted instead of T₂ weighted
  - Prone to artifacts
- Shorter TR
  - Short scan time
  - 3D and breath hold acquisitions
  - and typically with FA < 90°
  - Lower RF energy deposition per TR than SE
  - But not necessary lower SAR

3D GRE

Spoiling

- Destroy magnetization build up in the transverse plane.
  - TR >> T₁ or T₂ (transverse relaxation)
  - Crusher gradients (gradient spoiling)
  - Change the phase RF excitation pulse (RF spoiling)
- Suppress signal from remaining Mₓ from previous TR
  - different spatial encoding -> artifacts
  - T₂ weighting -> contrast alteration
Flavors of GRE Sequence

• Spoiled GRE:
  – FLASH/SPGR/T1-FFE
  – Multi-echo spoiled GRE
  – MEDIC
  – VIBE
• Un-spoiled/Rewound/Coherent GRE:
  – FISP/GRASS/FFE
  – PSIF/SSFP/T2-FFE
  – TrueFISP/FIESTA/b-FFE
  – CISS/FIESTA-C
  – DESS

FLASH Applications

• $T_1$ weighed anatomical
• DCE imaging and perfusion ($T_1$ change with contrast concentration)
• CE MRA ($T_2$ reduction due to contrast agent)
• TOF MRA ($T_1$ reduction due to inflow)
• PC MRA
• SWI ($T_2^*$ reduction due to deoxyhemoglobin in venous blood)
• $B_0$ and $B_1$ field mapping

2D FLASH/SPGR/FFE-T1

• Only use signal only from gradient echo.
• Signal is $T_1$ and $T_2^*$ weighted and flip angle dependent:
  \[
  S = \rho \frac{\sin \alpha [1 - e^{-TR/T1}] - e^{-TR/T2}}{1 - \cos \alpha e^{-TR/T2}}
  \]
• Ernst condition:
  \[
  \alpha_{\text{Ernst}} = \cos^{-1} \left[ e^{-TR/T1} \right]
  \]

2D/3D FLASH Example @ 3T

• Use High rBW to minimize susceptibility artifacts
• Use in-phase TE to keep fat bright

In and Out of Phase for Water and Fat

TE: 0 ms
2.25 ms
4.5 ms

\[
\begin{align*}
S_{\text{w}}(\text{TE}_{\text{in}}) &= S_{\text{w}} - S_{\text{f}}(\text{TE}_{\text{out}}) \\
S_{\text{w}}(\text{TE}_{\text{out}}) &= S_{\text{w}} + S_{\text{f}}(\text{TE}_{\text{in}}) \\
S_{\text{f}} &= \frac{S_{\text{w}}(\text{TE}_{\text{in}}) + S_{\text{w}}(\text{TE}_{\text{out}})}{2}; \ S_{\text{f}}(\text{TE}_{\text{out}}) = S_{\text{f}}(\text{TE}_{\text{in}}) - S_{\text{f}}(\text{TE}_{\text{out}})/2
\end{align*}
\]

Two-point and Three-point DIXON

\[
\begin{align*}
\alpha(\theta_0) = \alpha(\theta_{\text{in}}) \\
\alpha(\theta_0) = \alpha(\theta_{\text{in}}) \\
\alpha(\theta_0) = \alpha(\theta_{\text{in}})
\end{align*}
\]
**DIXON Example**

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**B₀ Field Mapping**

\[ \Delta \phi = 2\pi \Delta B₁(TE₂-TE₁) \]

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**Multi-echo (ME) Spoiled GRE**

\[ T₂^* \text{ Quantification/Mapping} \]

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**T₂* Mapping Applications**

- Cartilage: Early detection of biochemical changes
- Liver and myocardium: Estimation of iron concentration

*Cartilage T₂ Map*  
*Cartilage T₂* Map

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**MEDIC: Multi Echo Data Image Combination**

Magnitude images from each echo are combined using sum of squares algorithm

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**MEDIC Application**

Cartilage lesions (arrow)

FLASH versus MEDIC

VIBE: Volume Interpolated Breath-hold Examination

VIBE Application

VIEWS: Volume Interpolated Examinations with Water-Stimulation

FISP versus PSIF

TrueFISP/FIESTA/bFFE
**TrueFISP/FLASH Setup**

- Sequence type: TrueFISP → GRE
- Segments: 20 → 7
- Flip angle (°): 60 → 12
- Bandwidth (Hz/pixel): 390 → 794
- TR: 39.27 → 20.78 ms
- TE: 157 → 3.41 ms

**TrueFISP Applications**

- **Imaging of Fluid**
  - Cardiac (Bright blood imaging)
  - MSK (Fluid in the joint space)
  - Non-contrast MRA (High signal from blood)
- **Fast acquisition**
  - Cardiac (Real-time imaging)
  - Fetal imaging

**TrueFISP and FLASH Example**

**Off-resonance Effect**

- To Reduce phase accumulation between excitation:
  - Improve $B_0$ homogeneity
  - Reduce TR

**CISS – Constructive Interference Steady State**

**DESS – Double Echo Steady State**
WE-DESS Imaging of Ligament

FLASH vs FISP vs DESS

Thank You!

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