Inversion Recovery (IR) Techniques and Applications

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The Anatomy of Basic MR Pulse Sequences

Magnetization Preparation Section
- Chemical Shift Selective Saturation & Excitation
- Spatial Selective Saturation
- Magnetization Transfer (MT)
- Inversion Recovery (IR)

Data Acquisition Section
- Slice/Shot Selective Excitation
- Echo Generation
- Gradient-Recalled Echo (GRE), Single-shot FSE (HASTE)
- Diffusion Weighting (DWI/DTI) and Gradient Moment Nulling (GMN)
- Frequency Encoding
- Filling of k-space

Magnetization Recovery Section
- End of Sequence Spoiling
- Driven Equilibrium

Variations of IR Technique

Inversion Options:
- Non-selective
- Slice-selective
- Spectral selective
- Adiabatic
- Flow-induced Adiabatic
- Combination of multiple inversions

Acquisition Options:
- Unlimited (TSE and TFL are common)
- 2D and 3D
- View ordering and correction of k-space modulation can be important.

Applications of IR

- Selectively suppress tissue / background signal based on T1 differences
  - STIR
  - FLAIR
  - SPAIR
- Improve T1 contrast (Phase Sensitive Recon)
  - MP-RAGE, IR-SPGR, IR-TFE
  - T1 FLAIR
  - T1 IR
- T1 Measurement / T1 Mapping
- Tagging / Labeling
  - Non-CE perfusion with Arterial Spin Labeling (ASL)

STIR, FLAIR, TI and TI_null

STIR: Short Tau Inversion Recovery, TRIM
FLAIR: FLuid Attenuated Inversion Recovery, “Dark Fluid”
**T1 of Various Tissue Types**

<table>
<thead>
<tr>
<th>Tissue</th>
<th>T1 @ 1.5T (msec)</th>
<th>T1 @ 3.0T (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSF</td>
<td>4400</td>
<td>4500</td>
</tr>
<tr>
<td>WM</td>
<td>780</td>
<td>850</td>
</tr>
<tr>
<td>GM</td>
<td>920</td>
<td>1330</td>
</tr>
<tr>
<td>Blood</td>
<td>1200</td>
<td>1500</td>
</tr>
<tr>
<td>Muscle</td>
<td>870</td>
<td>1160</td>
</tr>
<tr>
<td>Fat</td>
<td>220</td>
<td>260</td>
</tr>
</tbody>
</table>

\[ T_{1\text{null}} = 0.69 \times T1 \]

**Dependence on Inversion Flip Angle and TR**

As the inversion flip angle or TR decreases:
- \( T_{1\text{null}} \) also decreases.
- Suppression becomes less selective.

**Interleave of Inversion & Acquisition**

**More about STIR**

- In-sensitive to \( B_0 \) inhomogeneity
  - More reliable than FATSAT for large FOV and off-center
  - Works at lower field strengths
- High visibility for fluid
  - Long T1 bright on STIR
  - Long T2 bright on STIR, given long enough TE
- Lower SNR
  - Improved with shorter TE (17-48 msec)
- Bad idea with Gd
  - Shorter post-contrast tumor T1
- Red marrow signal can obscure subtle edema
  - Use TE=45-48+ to suppress marrow

**STIR versus FATSAT in the Presence of Metal “Hardware”**

**81 year old female, right hip prosthesis**

Cor CT  
Cor FSE T2 with FATSAT  
Cor STIR
Modified STIR for MSK

- TE=50-100; Ti=110-120 @ 1.5T
- Improved SNR and excellent fluid sensitivity in soft tissues

Water Saturation plus STIR for Imaging Silicone Implant

STIR
- Improved SNR and excellent fluid sensitivity in soft tissues

FLAIR (Dark Fluid) for Brain

FLAIR (Modified FLAIR)

- Used short TR and TI than conventional FLAIR
- Suppress CSF and provides T1 contrast

SPAIR – SPectrally Adiabatic Inversion Recovery

- SPAIR uses an adiabatic frequency selective inversion pulse.
- Insensitivity to B1 inhomogeneity (better for 3.0T)
- Takes longer time and generates higher SAR than conventional ChemSat

Conventional vs Adiabatic Inversion
Dark Blood for Cardiac Applications

Cardiac Morphology with DIR

DIR for Brain

Inversion-Recovery for ON-resonant water suppression (IRON)

Triple IR (TIR) or DB STIR

DIR versus TIR
DIR Optimization for Cardiac

- TR too short: systolic motion reduces myocardial signal
- TR optimized
- TR too long: blood signal begins to recover

Adjust TI according to Heart Rate or TR (Lock Contrast)

<table>
<thead>
<tr>
<th>Heart Rate BPM</th>
<th>RR msec</th>
<th>TR msec</th>
<th>TI msec</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>600</td>
<td>1200</td>
<td>420</td>
</tr>
<tr>
<td>80</td>
<td>750</td>
<td>1500</td>
<td>550</td>
</tr>
<tr>
<td>60</td>
<td>1000</td>
<td>2000</td>
<td>630</td>
</tr>
</tbody>
</table>

T1 In-sensitive DB with Quad IR

- QIR
- DIR

Small FOV with Quad IR

Background Suppression with IR in Renal MRA

Improve Tissue Contrast with IR

- MPRAGE T1 @ 3T: 0.9x0.9x0.9 mm³; TA: 4:31
**T1-weighted FLuid-Attenuated Inversion Recovery (T1FLAIR)**

- Axial T1 FLAIR @ 3T with TR/TE/TI/ETL = 2100/9.5/900/3
- Improves T1 contrast at 3.0T
- High SAR limits number of slices and coverage

**Myocardial Viability (Delay Enhancement)**

- Increased distribution volume of contrast within necrotic myocardium.
- Necrotic tissue has faster T1 recovery than normal tissue following an IR pulse.
- Adjusting the TI to null normal myocardium gives maximum image contrast between necrotic and normal myocardium tissues.

**Suppress Normal Myocardium with IR**

- ECG
- Trigger
- Non-selective 180° inversion
- Necrotic
- Normal
- Non-selective 180° inversion
- Necrotic
- Normal
- Non-selective 180° inversion
IR FLASH/TruFISP/EPI for Delayed Enhancement

Suppress the signal from normal myocardium


T₁ Scout

T₁ Scout

IR with Phase Sensitive (PS) Recon

IR with Phase Sensitive (PS) Recon

True IR (Real IR) for Brain

True IR (Real IR) for Brain

PS T₁IR

PS T₁IR

Hou et al. AJNR 2005 26 (6): 1432

Phase Sensitive Reconstruction

Phase Sensitive Reconstruction

- An image reconstruction option, no additional scan time
- Improve contrast
- May produce artifact.

Ask for both magnitude recon and PS recon images.
Summary

- Inversion Recovery (IR) is a useful technique to improve tissue contrast based on their T1 differences.
- The improvement typically come with a cost of lower SNR and longer time.
- Multiple IRs targeting different species can be combined in a single acquisition.