Lecture-14B — Magnetization Preparation
Saturation, Inversion, and Contrast Preparations

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Learning Objectives

• Describe several forms of saturation pulse
• List and explain three uses of inversion nulling
• Describe T2-prep sequences and their effect
• Describe a driven-equilibrium sequence
• Explain magnetization transfer and CEST
• Explain long-T2 suppression
• Qualitatively describe diffusion encoding
Fat Saturation

- Chemically-selective excitation
- Dephaser gradient
- Normal imaging sequence
Spatial Saturation

- Reduced FOV imaging
- Saturate “bands” outside FOV to prevent aliasing

Image: Spatial saturation ("Outer volume suppression") selectively crops the field-of-view before imaging.

Courtesy Valentina Taviani, Andreas Loening
Spatial Saturation

- Use with arbitrary sequences
  - Save time with reduced FOV
- Very selective w/o time penalty
- Cosine modulate (dual-band)
  - Osorio JA, et al. MRM 2009
Myocardial Tagging

- Spatially selective saturation pattern (lines, grid)
- Often ‘cine’ acquisition

Exciting a pattern in the heart can allow visualization of cardiac motion

Courtesy J. Zwanenburg (MRM 2003)
Inversion-Recovery Nulling (STIR)

- Fat suppression based on $T_1$
- Short TI Inversion Recovery (STIR)
STIR vs Fat Saturation

- STIR is T₁-based and less sensitive to B₀ variations
- STIR costs SNR
- STIR can suppress gadolinium-enhanced signal (Short-T₁)
Fluid-Attenuated Inversion Recovery (FLAIR)

- **Fluid suppression based on $T_1$**
Question 1: Inversion Nulling

What is the TI time to null fat ($T_1 = 250\text{ms}$) and CSF ($T_1 = 2000\text{ms}$)?

Hint: $e^{-0.7} \approx 0.5$

$TI = (0.7) T_1$

TI for fat is about 175 ms

TI for CSF is about 1.4 s
IR Prep to enhance T1 contrast

• Often used with GRE (MP-RAGE)
• Example: Cardiac CINE, IR at start (note septum)
Mag-Prep: Inflow-enhanced MRA

- Preparation:
- Background Suppression
- Fat Suppression

Courtesy Pauline Worters
Question 2: Inversion-Recovery Flip Angle

If the inversion is too low (say 160°) what happens to the recovery curve (shape, null-point time)?

- Curve shifts up (m₀-m(0) decreases)
- Null occurs earlier

How might you address the imperfect flip angle?

- Model the “inversion efficiency” in T₁ fitting
- Use adiabatic inversion pulses
T2-Prep (Enhance T2 contrast)

- Tip magnetization into transverse plane
- Restore magnetization following some $T_2$ decay

Regular Imaging Sequence

T2-prep + Fat-Sat Renal Artery
IR + T2-Prep: Flow-Independent Angiography

- Inversion: Suppress synovial fluid
- T2-prep: Arterial-venous contrast
Question 3: T2-prep

What are pros/cons of using refocusing pulses in a T2-prep sequence?

- Reduce sensitivity to B0
- Increases RF power / SAR

If varying T2-prep lengths are used to measure T2, what is the effect of T2-contrast in the sequence?

- No effect! T2-contrast just scales the T2-prep contrast
Fast Recovery or Driven Equilibrium “Tip-up”

- After sequence, restore transverse magnetization
- Enhances $T_1$ recovery, if $T_2$ is long!
- Contrast becomes $T_2/T_1$ weighted

Fast recovery restores residual transverse magnetization to the $M_z$ to speed recovery
Fast Recovery (FR) or Driven Equilibrium

- Enhances fluid signal

Fast-recovery tips residual transverse magnetization to $M_z$ - Enhances fluid signal
Magnetization Transfer (MT)

- Saturate very-short-$T_2$ water bound to macromolecules
- MT effect causes saturation of free water (signal loss)
- More RF generally causes more MT saturation (adverse)
- CEST: Saturation at specific frequency

\[ MTR = \frac{M_0 - M_{sat}}{M_0} \]
MT Example

- Interleaved multislice has off-resonance pulses (other slices!)
- MT saturation can suppress signals
Chemical Exchange Saturation Transfer (CEST)

Solute Pool ($P_s$) \hspace{1cm} Water Pool ($P_w$)

$$P_s \ll P_w$$

\[ \text{RF}_{\Delta \omega=3\text{ppm}} \]

\[ \text{RF}_{\Delta \omega=-3\text{ppm}} \]

\[ \text{MT + Spillover} \hspace{1cm} \text{CEST}_{\text{sym}} \]

$\Delta \omega$
MT and EPG

- "EPG-X: An Extended Phase Graph formalism for systems with Magnetization Transfer or Exchange." Malik SJ et al. MRM 2017
- Add state for bound Mz

\[
\begin{bmatrix}
\tilde{F}_n^a & \tilde{F}_n^{a*} & \tilde{Z}_n^a & \tilde{Z}_n^b
\end{bmatrix}^T
\]
Long-T2 Suppression

- Ultrashort TE (UTE) shows cortical bone, connective tissue
- Suppression of long-T2 tissue improves contrast
- Subtraction (short-long TE) or long-T2 suppression

Long-T2 suppression removes long-T2 signal from the image, leaving short T2 alone

Larson PZ, MRM 2006
Diffusion-Weighted Imaging (DWI)

RF

180°

$G_z$

No Diffusion

Diffusion

Low b-value

High b-value

ADC
Other Preparations

- Inflow suppression: Saturate upstream blood (spatially)
- Flow-sensitive suppression
- Double IR: Non-selective, then selective
  - “Black Blood”
- Multiple IR: Null multiple species simultaneously
- Arterial spin labeling (Invert blood, subtract reference)
- Diffusion preparation (with tip-up)
  - Motion-sensitized driven equilibrium (MSDE)
- Null vessel signal

There are many, many other magnetization preparation approaches used in MRI
Summary of Magnetization Preparation

- Modify contrast before an imaging sequence
- Suppression: remove / null signals:
  - Spatial Saturation, Fat Saturation, Blood, Fluid
- Contrast: alter contrast of sequence:
  - Inversion ($T_1$), $T_2$-prep, Diffusion, MT
- Encoding: Flow/motion, Diffusion, Tagging
How is diffusion preparation used for numerous applications?
Rad229 – MRI Signals and Sequences

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