Myocardial Viability Concepts
Myocardial Viability = Delayed Enhancement

- Increased distribution volume of contrast in necrotic myocardium
- Occurs within 5-30 minutes post-injection
- Delayed enhancement suggests acute necrosis or chronic fibrosis
Two Phases of Myocardial Enhancement

- Normal Myocardium
  - First-Pass: < 1 min
- Infarcted Myocardium
  - Delayed Enhancement: > 5 min
- Ischemic Myocardium
Two Phases of Myocardial Enhancement

- Normal Myocardium
- Infarcted Myocardium
- Ischemic Myocardium

Injection

Time:
- First-Pass: < 1 min
- Delayed Enhancement: > 5 min
Myocardial Viability
How does it work?

- Increased distribution volume of contrast agent within necrotic myocardium.

- Necrotic tissue has faster T1 recovery than normal tissue following an IR pulse.

- Adjusting the T1 to null normal myocardium gives maximum image contrast between necrotic and normal myocardium tissues.
Coronary Artery Territories

AHA Recommendations, Circulation Jan 29, 2002
Myocardial Viability
How does it work?

- Data gated to diastole of every other cardiac cycle
- TI adjusted to null normal myocardium
- Necrotic is brighter than normal myocardium
Myocardial Viability
Optimizing the TI is Critical

- Adjusting the Optimal TI depends on ...
  - Dose of contrast injection
  - Time between injection and imaging
  - Relaxation time between IR pulses (# heartbeats skipped)

- And TI is time dependent ...
  - Contrast agent in myocardium washes out with time
Myocardial Viability
What if you select the wrong TI with a typical Magnitude Reconstruction?

- if TI is too short -> reversed image contrast
- if TI is optimal -> optimal image contrast
- if TI is too long -> reduced image contrast
Myocardial Viability

What if you select the wrong TI with a typical Magnitude Reconstruction?

- TI = 110 msec
  - Too short
  - Reversed
  - Image contrast

- TI = 275 msec
  - Optimal
  - Ideal
  - Image contrast

- TI = 450 msec
  - Too long
  - Reduced
  - Image contrast
Myocardial Viability Sequences
TurboFLASH vs TrueFISP

**TurboFLASH**

- Spoiler Pulse + Unbalanced Gradients:
  - Insensitive to Field Inhomogeneity Artifacts
  - Lower SNR

**TrueFISP**

- Steady State + Balanced Gradients:
  - Plagued by Field Inhomogeneity Artifacts
  - Higher SNR
Myocardial Viability Pulse Sequences

IR TurboFLASH
25 lines/segment
40 heartbeats
2 averages

IR TrueFISP
61 lines/segment
16 heartbeats
2 averages

Canine heart, 2x dose, 1mm x 1mm x 5mm
Myocardial Viability Pulse Sequences

- **Segmented**
  - repeats every other heartbeat
  - 10-12 heartbeats needed per image

- **Single-shot**
  - repeats every other heartbeat
  - only 1 heartbeat needed per image

TR positions data in late diastolic gating
Myocardial Viability Pulse Sequences

Segmented:  
- IR TurboFLASH  
- 10 second breath-hold

Single-Shot:  
- IR TurboFLASH  
- Single heartbeat

Single-Shot:  
- IR TrueFISP  
- Single heartbeat

Segmented:  
- ✓ Best resolution  
- ✓ Best contrast  
- x Good Breathhold required  
- x Sensitive to arrhythmias

Single-Shot:  
- x Acceptable resolution  
- x Acceptable contrast  
- ✓ No breathhold required  
- ✓ Insensitive to arrhythmias
Myocardial Viability
Pulse Sequences

- Use Segmented for Cooperative Patients
- Use Single-Shot for UnCooperative Patients

Segmented IR TurboFLASH
- patient had poor breathhold
- gives poor image quality

Single-Shot IR TrueFISP
- patient had poor breathhold
- gives acceptable image quality
Myocardial Viability Pulse Sequences

- Use Segmented for Cooperative Patients
- Use Single-Shot for UnCooperative Patients

**Segmented IR TurboFLASH**
- requires good breathhold
- gives high resolution

**Single-Shot IR TrueFISP**
- no breathhold required
- gives acceptable resolution
Myocardial Viability
Pulse Sequences

- Very quick and robust survey of entire heart
- 10 images in 20 heartbeats
- Multiple different views

Single-Shot
IR
TrueFISP
Myocardial Viability Pulse Sequences

- Acquires a 3D volume in one breathhold
- Complete coverage of heart with thin slices in 2 - 3 breathholds
- Requires very cooperative patient with normal heart rate
- Very sensitive to optimal TI setting
- Triggered on every heartbeat, high bandwidth & short echo spacing

Segmented IR Flash 3D
Myocardial Viability
Which Pulse Sequences Should I Use?

1. IR TurboFLASH has been used for a number of years, and has been extensively studied in the literature. IR TrueFISP is relatively new, and has not been extensively studied in the literature.

2. For very cooperative patients with normal heart rates and no arrhythmias, the 3D Segmented IR FLASH sequence works well.

3. For moderately cooperative patients with very few arrhythmias, the 2D Segmented IR TurboFLASH sequence works well.

4. For uncooperative patients who can not breathhold or have significant arrhythmias, the 2D Single-Shot IR TrueFISP sequence works well.

5. If you have difficulty determining the optimal TI, use the TI-Scout sequence and/or the PSIR AutoViability sequence.
Myocardial Viability Optimization
Myocardial Viability Sequences for Optimizing TI

TI Scout
Displays wide range of TI's

PSIR AutoViability
Works over wide range of TI's
TI Scout
How does it work?

- IR pulse + data acquisition every other heartbeat
- Each cardiac phase has a different TI
- Playback in a cine loop and select best TI
TI Scout
Displays wide range of TI's

- Playback in a cine loop
- Stop at optimal image
- TT on image text is actually TI

Note:
- If 2D DE image is acquired every other heartbeat, then TI Scout should also be acquired every other heartbeat.
- If 3D DE image is acquired every single heartbeat, then TI Scout should also be acquired every single heartbeat.
PSIR AutoViability
How does it work?

- Phase Sensitive Inversion Recovery reconstruction maintains signal polarity.
- Image normalization allows post-acquisition windowing adjustment.
- Necrotic myocardium brighter than normal myocardium over broader range.

PSIR AutoViability
How does it work?

- Interleaved IR-prep acquisition and phase reference acquisition
- Requires two heartbeats per data segment

ECG
Trigger
IR pulse
Magnetization
Segmented Acquisition
IR-prep segment 1 (30°) T1-weighted
Ref segment 1 (5°) PD-weighted
IR-prep segment 2 (30°) T1-weighted
PSIR AutoViability
Works over broader range of TI

Magnitude

TI = 150 msec too short

TI = 200 msec

TI = 250 msec optimal

TI = 300 msec

TI = 350 msec too long

PSIR AutoViability
PSIR AutoViability

Works over broader range of TI

PSIR AutoViability

TI too short  TI optimal  TI too long

Magnitude