2013 SPR Cardiac Session

What is it?
Black Blood Imaging

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Disclosure

- No financial disclosure relevant to the subject matter of this presentation
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• I am not a physicist
Acknowledgement

• All the nice slides belongs to Raja Muthupillai
SAM question

• For black blood imaging using inversion recovery technique, it is best to have a single inversion pulse to null the blood as there is enough difference between the T1 of myocardium and blood such that the myocardium will be seen well

• True or False
Black Blood Imaging

- Two main sequences
  - Basic Spin Echo
    - Faster Variants of Basic SE (TSE / EPI)
  - Double Inversion Black-Blood Imaging
    - Variants of Double Inversion
Spin Echo Black Blood Imaging

- Simple Spin Echo Imaging
  - Outflow of Spins from the imaging volume between the 90° and the 180° degree pulses
Spin Echo BB Imaging: Technique

- ECG triggered Scan
- TR = 1 heart beat
- Multi-Slice Acquisition
SE (SE-EPI / SE-TSE): Summary

• Cardiac Triggered Scans; free-breathing
• Use TE = 15 - 20 ms to achieve black blood (TOF effect)
• Multi-Slice Acquisitions - Quick BB Survey of Anatomy
• Use Multiple NSA (in combination with EPI/TSE)
• Use Saturation pulses (to minimize inflow or fat ghosting)
• Both T1 and T2 weighting is possible
• T2W important in edema imaging
  - Set TE = 60 ms
  - Set TR = 2 to 4 heart beats (to achieve TR = 2000 ms)
Sedated 6-day-old infant – double aortic arch

3 mm thick / 10% gap 1.6 mm thick / 10% gap

VCG-triggered Spin echo T1W EPI (5 shots) with saturation bands
FOV 240mm, 256 x 512(recon), **SENSE factor 2, 8 NSA**
16 slices, HR = 123 bpm; TR/TE = 480/15 ms; **scan time 3:14 mins**
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Sedated 6-month-old infant with Coarctation Combining EPI, SENSE, Respiratory Triggering

VCG-triggered Spin echo EPI (5 shots); 2mm thick, no skip FOV 260mm, 256 x 256; SENSE factor 2, 4 NSA, Resp Trig 16 slices, \( HR = 130 \text{ bpm} \); TR/TE = 462/15 ms; scan time 3 - 4 mins
VCG-triggered Spin echo EPI (5 shots); 2mm thick, no skip
FOV 260mm, 256 x 256;  SENSE factor 2, 4 NSA, Resp Trig
16 slices, HR = 130 bpm; TR/TE  = 462/15 ms; scan time 3 - 4 mins
Edema imaging
Freely breathing sedated 10-year-old boy S/P cardiac arrest

Turbo spin echo T2W (Turbo factor 30) with fat suppression
Respiratory triggered, 2 NSA’s, SENSE = 1.5
1.4 x 1.8 x 8 mm; TR = 2 HBs (HR 55), TE = 60
Conventional Spin Echo: Limitations
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- Conventional SE is time consuming
  - Faster Acquisition Techniques - TSE, EPI, + SENSE
Conventional Spin Echo: Limitations

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  - Faster Acquisition Techniques - TSE, EPI, + SENSE
- Blood Signal Suppression depends on Spin Velocity
  - Incomplete suppression of slow flow
  - Less of a problem in infants and younger patients
  - In-plane flow is problematic
Conventional Spin Echo: Limitations

• Conventional SE is time consuming
  – Faster Acquisition Techniques - TSE, EPI, + SENSE
• Blood Signal Suppression depends on Spin Velocity
  – Incomplete suppression of slow flow
  – Less of a problem in infants and younger patients
  – In-plane flow is problematic

• Alternative: Inversion recovery (like FLAIR, ‘STIR’)
  – Most optimal with breath-holding
  – Can use multiple NSA for free breathing scan but long scan
Single Inversion BB Imaging

- ECG triggered Scan
- TR = 1 or 2 heart beats
- 2D / M2D Acquisition
- TSE Readout / BH
Single Inversion BB Imaging

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Double Inversion BB Imaging

--- Myocardium

--- Blood
Double Inversion BB Imaging

- • The first non-selective inversion inverts everything
Double Inversion BB Imaging

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Myocardium
Blood
Double Inversion BB Imaging

- The first non-selective inversion inverts everything
- The second selective inversion pulse re-inverts the signal within slice

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Myocardium
Blood
Single Vs Double Inversion BB

Single IR  
Dual IR

Note the increased SI in the myocardium in the Dual IR!  
(for the same TR/TE/TI as the Single IR sequence)
Choose correct TI:

- The Inversion Delay should be adjusted for Heart Rate (or TR) to improve nulling of blood signal

<table>
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<th>HR (bpm)</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
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<tbody>
<tr>
<td>TR (2hb)</td>
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<td>2400</td>
<td>2000</td>
<td>1714</td>
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<td>1333</td>
<td>1200</td>
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<td>1000</td>
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<td>TI (msec)</td>
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<td>679</td>
<td>624</td>
<td>574</td>
<td>529</td>
<td>490</td>
<td>456</td>
<td>426</td>
<td>399</td>
<td>375</td>
</tr>
</tbody>
</table>
Calculating the correct TI

\[ TI = \ln\left(\frac{2}{(1 + \exp(-TR / T_1))}\right)T_1 \]

Blood \( T_1 = 1200 \text{ msec} \)

For Post Contrast Scans, \( TI \) needs to be shorter to null CE-Blood.
Example of incorrect TI

DIR - T1W

DIR - T1W post Gad without change in TI with fat sat (inhomogeneous)
Choose Long enough TR!

- At higher HR, keep TR > 1500 msec, for good signal from myocardium!

\[ TR = 800 \text{ msec} \quad \text{TR} = 1600 \text{ msec} \]
Double IR Turbo Spin Echo

Non-breath-hold

TR = 3 R-R; TE = 65; TSE factor 27; FOV = 360; 230 x 512 (r)
4 mm thick / gap 2 mm; 3 slices; 4 NSA’s; scan time 2:30 min
Double IR Turbo Spin Echo

4 NSA, non breath hold

2 NSA/resp trig, non breath hold
Anesthesized 3.1 kg neonate with heterotaxy
? pulmonary vein anatomy

Breath-holding double inversion recovery turbo spin echo
1.8 mm thick, no skip, 0.8 x 1.1 mm, 2 NSA
TR= 2RR, TE 40, ~ 12 sec / slice

Courtesy of Andrew Powell, David Annese, Children’s Hospital, Boston
Triple inversion recovery

Cardiac fibroma – better conspicuity with triple IR
T2W TSE with fat sat  Triple IR
Freely breathing sedated 3-month-old with Kawasaki disease

Vessel wall inflammation showed on triple inversion recovery with 3 NSA’s
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- Considering using parallel imaging to decrease acquisition duration/heart beat if needed
- Adjust parameters for appropriate breath-hold duration
- Can use 3 NSA’s or respiratory trigger for free breathing
  - Can result in long scan time
SAM question

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• True or False
SAM question

• For black blood imaging using inversion recovery technique, it is best to have a single inversion pulse to null the blood as there is enough difference between the T1 of myocardium and blood such that the myocardium will be seen well

• False: need 2 inversion pulses (non-selective and slice selective)

• Mulkern RV, Chung T. From signal to image: magnetic resonance imaging physics for cardiac MR. Pediatr Cardiol 2000; 21:5-17
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