T2-weighted Imaging for Improved Lesion Characterization in Breast MRI

Catherine J. Moran, PhD

NCI Cancer Imaging Fellowship Seminar
June 20, 2012
1. Motivation and Background

2. Evaluation of 3D T2-weighted Imaging

3. Double Echo Steady State T2-mapping: Initial Results
1. Motivation and Background
Clinical Motivation

- Most commonly diagnosed cancer
- Second most deadly cancer
- MRI: diagnosis and treatment planning

Source: American Cancer Society, 2009.
Clinical Motivation

✧ Most commonly diagnosed cancer

✧ Second most deadly cancer

✧ MRI: diagnosis and treatment planning

✧ Improve lesion characterization with MRI

Source: American Cancer Society, 2009.
Breast MRI

• Centerpiece of breast MRI is Dynamic Contrast Enhanced (DCE-MRI)

• T1-weighted contrast

• Intravenous paramagnetic contrast agent that shortens T1

• Uptake of contrast greatly improves conspicuity of lesions
Breast MRI

- Centerpiece of breast MRI is Dynamic Contrast Enhanced (DCE-MRI)
- T1-weighted contrast
- Intravenous paramagnetic contrast agent that shortens T1

pre-contrast

post-contrast
DCE MRI in the Breast

• DCE-MRI has very high sensitivity (89-100%)\cite{Majid2003}

- DCE-MRI has very high sensitivity (89-100%)\textsuperscript{1}
DCE MRI in the Breast

- DCE-MRI has very high sensitivity (89-100%)\(^1\)
- Specificity of breast MRI is variable (30-97%)\(^2\)


T2-Weighted Imaging in Breast MRI

• Adjunct to Dynamic Contrast Enhanced Images
• Routine part of Breast MRI, identification of cysts
• Information that can contribute to lesion characterization

1. Contrast of lesion to surrounding fibro glandular tissues
   • Malignant lesions tend to have low T2 weighted signal
   • Benign lesions tend to have high T2 weighted signal

2. Lesion morphology
T2-Weighted Imaging in Breast MRI

Pre Contrast Injection

DCE (Contrast Enhanced)

T2 Weighted
Limitations of T2-weighted Imaging

- Necessity for long TR, short signal duration

\[
\begin{align*}
T2 &< 200 \text{ ms} \\
T1 &= 200-3000 \text{ ms}
\end{align*}
\]
Limitations of T2-weighted Imaging

- Necessity for long TR, short signal duration

Long scan times for high resolution

Acquired in 2D with low through-plane resolution
Limitations of T2-weighted Imaging

- Necessity for long TR, short signal duration

  
  RF

  Signal

  - Partial volume effect can obscure lesion morphology
  - Poor alignment with DCE images
Summary: T2-weighted Imaging in breast MRI

- Variable specificity
- Diagnostic information in T2-weighted imaging
- Inherent limitations of T2-imaging
- Undervalued and underutilized
1. Motivation and Background

2. Evaluation of 3D T2-weighted Imaging

3. Double Echo Steady State T2-mapping: Initial Results
2. Evaluation of 3D T2-weighted Imaging
Extended Echo Train T2-weighted Imaging

RF

Signal
Extended Echo Train T2-weighted Imaging

- 3D T2-weighted imaging
- Not purely T2-weighted
3D T2-weighted Imaging

- clinically available
  - CUBE (GE)
  - SPACE (Siemens)
  - VISTA (Phillips)

- validation in vivo
  - Meniscus (Kijowski, et al., *Skel Rad*, 2011)
  - Ganglion cysts (Shahid, et al., *JMRI*, 2010)
  - Ankle (Stevens, et al., *Radiology*, 2008)
  - Uterine abnormalities (Agrawal, et al., *AJR*, 2009)
3D Extended Echo Train Breast MRI

Goal of this work to assess the 3D T2-weighted CUBE sequence, in vivo in the breast in comparison to a conventional 2D Fast Spin Echo Sequence

- Contrast between lesions and surrounding tissues
- Impact of improved resolution
3D Extended Echo Train Imaging in the Breast

Subjects

• 27 patients

• CUBE and FSE acquired as part of breast MRI

• Clinically indicated breast MRIs
  • High-risk screening (12)
  • Preoperative staging (5)
  • Response to treatment (5)
  • Diagnostic (5)
3D Extended Echo Train Imaging in the Breast

Subjects

- 27 patients
- 17 lesions
  - 7 Invasive Ductal Carcinomas (IDC)
  - 5 fibroadenomas, 1 papilloma, 3 cysts, 1 cyst/hematoma
## Imaging Parameters

<table>
<thead>
<tr>
<th></th>
<th>FSE</th>
<th>CUBE</th>
<th>DCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Matrix</strong></td>
<td>320 x 256</td>
<td>320 x 256</td>
<td>236 x 366</td>
</tr>
<tr>
<td><strong>Slice Thickness</strong></td>
<td>4 mm</td>
<td>2 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td><strong>Number Slices</strong></td>
<td>46</td>
<td>192</td>
<td>364</td>
</tr>
<tr>
<td><strong>Scan Time</strong></td>
<td>5 min</td>
<td>5 min</td>
<td>----</td>
</tr>
</tbody>
</table>
3D Extended Echo Train Imaging in the Breast

Analysis

• Lesion-to-fibro glandular tissue signal

• Unblinded review by radiologist

• Effect of resolution
Lesion-to-Fibroglanular Tissue Signal Ratio
Small Enhancing Fibroadenoma

DCE  FSE  CUBE
Benign Papilloma

DCE - Axial

FSE - Axial

CUBE - Axial

DCE - Sagittal

FSE - Sagittal

CUBE - Sagittal
3D Extended Echo Train Imaging in the Breast

Contrast

Lesion-to-fibro glandular tissue contrast well correlated

More accurate depiction of contrast in small lesions

Resolution

Improved alignment with DCE findings

Improved depiction of lesion morphology
3D Extended Echo Train Imaging in the Breast

Conclusion:

3D T2-weighted acquisitions may improve the contribution of T2-weighted imaging in breast MRI through higher resolution without detriment to T2-weighted contrast

** based on this initial assessment, CUBE is now the T2-weighted sequence utilized clinically at Stanford
1. Motivation and Background

2. Evaluation of 3D T2-weighted Imaging

3. Double Echo Steady State T2-mapping: Initial Results
3. Double Echo Steady State T2-mapping: Initial Results
Quantitative T2-mapping in the breast

- Lesion signal intensity on T2-weighted images is relative
- Large variability in signal intensity across normal tissue
Quantitative T2-mapping in the breast

• Signal intensity on T2-weighted images is relative
• Large variability in signal intensity across normal tissue
• Two previous studies of T2-values in breast lesions
• Early on – low resolution, image quality
T2-mapping

• Time consuming

• Not practical in-vivo
DESS

- Dual Echo Steady State

- Gradient echo so more efficient than spin echo methods

T2-mapping with DESS

\[ T2 = \frac{2 \cdot (TR - TE)}{\ln(S^+/S^-)} \]

- Calculation of T2 is only valid for flip angles of 90°
- However at 90° SNR is very low

DESS

- Diffusion between the two echoes can limit the accuracy
- qDESS: both ADC and T2

*Staroswiecki, et al., MRM, 2011
DESS

T₂ estimate comparison

\[ y = 1.001x - 0.36 \]
\[ R = 0.989 \]

*Staroswiecki, et al., MRM, 2011*
DESS in the Breast Current Status

- DESS also provides ADC Maps
- Implementation in the breast*
- Focus on ADC
- Implemented clinically, consenting patients
- T2-maps
- Exploratory
- Preliminary results

*Granlund, K.
DESS

• DESS T2-maps for 11 patients

• Measured T2 value
  • Muscle
  • Fibroglandular tissue
  • Benign lesions
  • Malignant lesions
DESS

• DESS T2-maps for 11 patients

• Measured T2 value
  
  • Muscle
  
  • Fibroglandular tissue
  
  • Benign lesions
  
  • Malignant lesions

• Compared to literature T2 values (muscle and fibroglandular)

• Qualitative assessment of T2-maps
Lesions in 11 subject dataset

- 10 malignant (8 IDC, 1 ILC, 1 DCIS) lesions
- 3 benign (2 UDH, 1 ALH) lesions
- 3 benign (1 cyst, 2 hematomas) lesions
T2-mapping in the breast
<table>
<thead>
<tr>
<th>T2 (ms)</th>
<th>Literature</th>
<th>DESS T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle</td>
<td>27 ± 2, 29 ± 4</td>
<td>24.4 ± 4</td>
</tr>
<tr>
<td>Fibroglandular</td>
<td>54.4 ± 9</td>
<td>44.2 ± 16</td>
</tr>
</tbody>
</table>
T2-mapping in the breast

T2 (ms)

- Muscle
- Fibrous Tissue
- Benign Lesions
- Malignant Lesions
T2-mapping in Malignant Lesions

T2-weighted (FSE)

IDC (1)

IDC (3)

DESS T2-maps
DESS T2-mapping in the Breast

• DESS T2 values correlated with spin echo values

• Investigation of T2-values in-vivo in the breast

• Preliminary results

• Validation of T2-values in vivo in normal breast tissue

• Defining hypothesis for T2-mapping in breast MRI
Clinical Motivation

✧ Improve lesion characterization with MRI

✧ Evaluation of 3D T2-weighted Imaging

✧ DESS T2-mapping in the breast
Acknowledgements

Brian Hargreaves  Anne Sawyer  Jafi Lipson
Bruce Daniel  Kevin Epperson  Jennifer Kao
Manoj Saranathan
Anderson Nnewihe
Kristin Granlund
Kyung Sung
Marc Alley
Bragi Sveinsson

**Volunteers**