Breast MR Imaging Techniques
and
Clinical Applications

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MRI Clinical Scientist

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Sofia, Suite Hotel 2016
Breast MR Imaging Techniques and Clinical Applications
Breast is the most diagnosed cancer in the 25 countries of Europe

<table>
<thead>
<tr>
<th>Cancer Type</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prostate</td>
<td>1.252M</td>
<td></td>
</tr>
<tr>
<td>Lung &amp; bronchus</td>
<td>15.5%</td>
<td></td>
</tr>
<tr>
<td>Colon &amp; rectum</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>Urinary bladder</td>
<td>6.6%</td>
<td></td>
</tr>
<tr>
<td>Oral cavity and pharynx</td>
<td>4.4%</td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Non Hodgkin Lymphoma</td>
<td>3.2%</td>
<td></td>
</tr>
<tr>
<td>Kidney</td>
<td>3.1%</td>
<td></td>
</tr>
<tr>
<td>Liver &amp; bile duct</td>
<td>2.7%</td>
<td></td>
</tr>
<tr>
<td>Leukemia</td>
<td>2.7%</td>
<td></td>
</tr>
<tr>
<td>Pancreas</td>
<td>2.4%</td>
<td></td>
</tr>
<tr>
<td>Esophagus</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>All other sites</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.036M</td>
<td>30.9%</td>
</tr>
<tr>
<td>Colon &amp; rectum</td>
<td>12.9%</td>
<td></td>
</tr>
<tr>
<td>Uterine corpus</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Lung &amp; bronchus</td>
<td>6.9%</td>
<td></td>
</tr>
<tr>
<td>Ovary</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Non Hodgkin lymphoma</td>
<td>3.2%</td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>2.9%</td>
<td></td>
</tr>
<tr>
<td>Pancreas</td>
<td>2.7%</td>
<td></td>
</tr>
<tr>
<td>Leukemia</td>
<td>2.5%</td>
<td></td>
</tr>
<tr>
<td>Kidney</td>
<td>2.3%</td>
<td></td>
</tr>
<tr>
<td>Bladder</td>
<td>2.1%</td>
<td></td>
</tr>
<tr>
<td>All other sites</td>
<td>21.6%</td>
<td></td>
</tr>
</tbody>
</table>
MRI can be used to obtain three dimensional images of the inner parts of the human body, without using X-rays...

MRI breast imaging is a supplemental tool, in addition to mammography, to help diagnose breast cancer
MRI advantages over X-ray or PET

- No radiation
- The ability to generate arbitrary 3D views
- Possibility to generate images of “soft” body structures
MRI advantages over X-ray or PET

- Can image breast implants and ruptures
- Highly sensitive to small abnormalities
- Used effectively in dense breasts
- Can evaluate inverted nipples for evidence of cancer
- Can evaluate the extent of breast cancer
- Can help determine what type of surgery is indicated (lumpectomy or mastectomy)
- May detect breast cancer recurrences and residual tumors after lumpectomy
- Can locate primary tumor in women whose cancer has spread to axillary (armpit) lymph nodes
- Can spot or characterize small abnormalities missed by mammography
- May be useful in screening women at high risk for breast cancer, according to recent studies
Limitations of Breast MRI

✓ MRI takes 30-60 minutes compared to 10-20 minutes for screening mammography
✓ The cost of MRI is several times the cost of mammography
✓ MRI requires the use of a contrast agent
✓ MRI patients must tolerate any claustrophobia
✓ MRI can be non-specific; often cannot distinguish between cancerous and non-cancerous tumors
✓ Minimally invasive breast biopsy techniques need to be further developed to evaluate abnormalities detected with MRI
✓ Advanced MRI techniques are often not available at most centers (currently available at research centers)
# Breast MR Imaging Techniques and Clinical Applications

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammography</td>
<td>90%</td>
</tr>
<tr>
<td>79%</td>
<td></td>
</tr>
<tr>
<td>MRI</td>
<td>90-</td>
</tr>
<tr>
<td>100%</td>
<td>37-97%</td>
</tr>
</tbody>
</table>

- **Mammography**: Sensitivity 79%, Specificity 90%
- **MRI**: Sensitivity 100%, Specificity 90-37-97%
Considerations…

- Enhancement Patterns and Dynamic curve
- Shimming is critical to obtain optimum fat saturated images
- Adjusting the center frequency over the water peak
- Fatty breasts are more susceptible to center frequency shifting to the fat peak
- Smaller breasts and low signal issue
- Bilateral breast imaging requires 4<Ch breast coils
- Correct ROI Measurements
Enhancement Patterns

85-95% Invasive Cancers enhanced fast in the initial phase. 10% Do not (Scirro and lobular Carcinoma)
Enhancement patterns

Benign $\rightarrow$ MALIGNANT

I  II  III  IV  V
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Left Dynamic Curve

Phase 1  Phase 2  Phase 3  Phase 4

Right

Concentration C(t)

Peak  Wash-in  Wash-out

TME  AUC  Time in sec
Dynamic Curve

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Signal increase

Precontrast 1. 2. 3. 4. 5. 6. 7. 8. Minutes after CM administration

Strong  Moderate  Slight
The following table illustrates the frequency differences between silicone, fat and water at varied field strengths.

<table>
<thead>
<tr>
<th>Component</th>
<th>1.5T</th>
<th></th>
<th>Component</th>
<th>3.0T</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>220 Hz less than water</td>
<td>Silicone</td>
<td>290 Hz less than water</td>
<td>440 Hz less than water</td>
<td></td>
</tr>
<tr>
<td>Silicone</td>
<td>100 Hz less than fat</td>
<td>Silicon from fat</td>
<td>580 Hz less than water</td>
<td>200 Hz less than fat</td>
<td></td>
</tr>
</tbody>
</table>
Using the wrong center frequency can result in poor image quality…

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The following table displays the desired suppression technique and default center frequency upon completion of prescan.

### Table 5-12: Suppression technique for 1.5T

<table>
<thead>
<tr>
<th>Suppression Technique</th>
<th>Default CF</th>
<th>Frequency shift at 1.5T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat saturation</td>
<td>Water peak</td>
<td>-220 Hz</td>
</tr>
<tr>
<td>Water saturation</td>
<td>Fat peak</td>
<td>+220 Hz</td>
</tr>
<tr>
<td>Silicon saturation (chose water saturation in the protocol)</td>
<td>Fat peak</td>
<td>-100 Hz</td>
</tr>
</tbody>
</table>

### Table 5-13: Suppression technique for 3.0T

<table>
<thead>
<tr>
<th>Suppression Technique</th>
<th>Default CF</th>
<th>Frequency shift at 1.5T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat saturation</td>
<td>Water peak</td>
<td>-440 Hz</td>
</tr>
<tr>
<td>Water saturation</td>
<td>Fat peak</td>
<td>+440 Hz</td>
</tr>
<tr>
<td>Silicon saturation (chose water saturation in the protocol)</td>
<td>Fat peak</td>
<td>-200 Hz</td>
</tr>
</tbody>
</table>
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FSE with no SAT Pulse shows Impermeability of implant

FSE-IR with WATER SAT Pulse shows Ruptures, dislocations, capsular contractures
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FSE-IR with Water SAT pulse and manual adjustment of CF location to suppress silicon

FSE T2 with Water SAT pulse Suppressing signals from cysts

Silicone suppressed typically used for tumor visualization

FSE-IR with WATER SAT Pulse shows Ruptures, dislocations, capsular contractures
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FSE T2 with Fat SAT

Imaging water filled cysts

Important!

• Saline implants: center on water peak
• Silicon implants: center on fat peak
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✓ When to scan
✓ How to scan
✓ Equipment
✓ Dosage and mode of Contrast injection
✓ Temporal Resolution
✓ Spatial Resolution
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When to scan?

☑ Pre-menopausal Patient:
  ☑ in the 2nd or 3rd week of her cycle

☑ 6 Months after surgery or open biopsy

☑ 12 Months after radiotherapy
How To Scan?

- Prone Position
- Wearing a stretch cloth
  
  Use of any compression or immobilizing devices may cause to change flow of blood in tumor or change the shape of lesion.
- Consider site of Injection in case of mastectomy.
- Rt. Hand for injection is the first choice.
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Equipments?

✓ 1.5T & 3.0Tesla
✓ 4 Ch Breast Coils and above
Dosage and mode of Contrast injection?

The recommended administration is 0.2ml/kg for normal breast.

For dense breast this can be 0.3ml/kg.

20ml saline solution should follow contrast agent injection at a rate of 2-3ml/s to flush the agent from tubing and arm vein.
Temporal Resolution;

Mainly 3D gradient-echo pulse sequences the center of K-space (in the Phase-encoding direction) is collected in about one-third of the way through the total acquisition.

For discrimination between pathological processes and surrounding parenchyma temporal resolution of 1-2 minutes per sequence with at least 5 measurements after Contrast administration is recommended.

Scan must continue between 6 to 8 minutes after injection.
Spatial Resolution

- 1-3mm thick slices
- Shortest TR speeds image acquisition
- Shortest TE minimizes T2*weighting of the sequence
- In sagittal plan matrix should be at least 256x256 and in axial or coronal planes should be at least 384x384
Post Processing; CAD Systems and Techniques

- Auto Registration
- Auto Segmentation
- Auto Visualization
CAD Software;

- Provides parametric maps, time course curves, 3D MIP, reformat, subtraction and registration
- Automatically identifies the 30 most “suspicious” ROIs based on time course data
- Conforms to ACR lexicon
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Suggested Breast MRI Protocols

- Axial T2 with FatSat / T2 STIR Bilateral
- Axial T1 (FSE)
- Axial DWI b500 and ↑
- Sag T2 with FatSat Unilateral
- Axial Dynamic (~7-10min post contrast)

Optional
- Spectroscopy
- MR Guided Biopsy
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VIBRANT

VIBRANT Flex

Paralel imaging
Calibration
Volume shim

No Paralel imaging!
No Calibration!
No Volume shim!
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Breast MRI Protocols

Fat Sat

In Phase

Dixon Technique

Water Sat

Out of Phase
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Breast MRI Protocols; DWI

DWI measures the mobility of water in tissue

Sensitive to characteristics often disrupted in malignant breast tissues, such as cell organization, density, extracellular space and cell membrane permeability

DWI may be useful for detecting breast cancer in a wide age group of women, including young women with dense mammary glands.*

A decrease in the apparent diffusion coefficient (ADC) provides strong evidence of malignant – type changes in the microstructure of a tissue. Relatively few data have been published worldwide, however and so the specificity of this sign is still uncertain.
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Breast MRI Protocols

Dynamic time course images demonstrating an enhancing lesion.

DWI-EPI images with b=700 demonstrating areas of low diffusion that correspond with the enhancing lesion.
Breast MRI Protocols: DWI

Use IR to suppress Fat signal in DWI
Literature appears to show that spectroscopy has a useful role in breast imaging with the presence of choline (3.25ppm) being a strong indicator of malignancy. A potential role has also been indicated in the assessment of early chemotherapy response.

A typical voxel size of 2cm x 2cm x 2cm at 1.5T takes approximately 3-5 minutes.

Additional SNR at 3.0T allows for a smaller voxel in the same scan time.
MR-Touch... MR Elastography

A unique and non-invasive method for evaluating tissue stiffness

- Non-invasive staging
- Early detection
- Reduce biopsy
- Patient biopsy refusal

Wave Image  Elastogram

Normal  Fibrosis  Cirrhosis

Tissue Stiffness

Shear Stiffness (kPa)
MR-Touch... MR Elastography

How does it work?

Vibration:
• Shear waves are generated in the tissue by an external acoustic driver

Imaging Sequence:
• The shear waves captured using multi-phase GRE with cyclic Motion-Encoding Gradient (MEG)

Motion Synthesis:
• The external acoustic driver is triggered by the PSD
  MEG gradient is synchronized with the external acoustic vibrations

Recon:
• Inversion algorithm is used to convert the wave images into a stiffness map (Elastogram)
By today MRI is capable...

**MRI... Morphology**
- T1... T2... T2*... Proton Density... SWI

**MRI... Function**
- Flow... Diffusion... Perfusion... BOLD

**MR-Elastography... Mechanical Properties**
- Propagating waves
- Soft Tissue Stiffness Contrast