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Adjunct Instructor
MRI Certificate Program
Miami Dade College
AHEC Faculty

BREAST MRI

Course outline

1. Anatomy of the breast
2. About breast cancer
3. Imaging coverage
4. Appropriateness criteria
5. Breast cancer risk models
6. Some technical issues in breast MRI
7. Positioning issues and pitfalls
8. Breast biopsy
9. Breast spectroscopy
10. Patient satisfaction scripting

BREAST MRI

Course objectives

Upon completion of this course the participants should be able to

1. Discuss the role of MRI in breast imaging
2. List the indications for breast MRI
3. Understand some of the technical factors critical to MRI of the breast
4. Have an understanding of biopsy of the breast under MRI guidance
5. Discuss some of the uses of breast MR spectroscopy
1. Lateral aspect of the pectoral region
2. Located between 3rd rib and 6th-7th ribs
3. Extends from sternum to the axilla
Cooper’s ligaments are bands of connective tissue that suspend the breast from the clavicle and fix it to the skin and to the deep fascia. The ligaments may retract in the presence of breast tumors causing dimpling or retraction of the nipple.

Tail of Spence often extends into the axilla.

Majority of breast cancers develop in the upper outer quadrant.
Most common cancers of the breast are either ductal or lobular.

Ductal is the most common type of breast cancers.

Triple negative breast cancers do not have estrogen nor progesterone receptors and do not have an excess of the HER2 protein in the surface of their cells.

They are more difficult to treat.
types of breast cancers

- Inflammatory breast cancer
- Paget's disease of the nipple
- Philloides tumors (cystosarcoma phillioide) can be benign or malignant and are removed surgically
- Medullary carcinoma
- Mucinous (colloid) carcinoma
- Papillary carcinoma
- Tubular carcinoma

What needs to be covered

1. 160 images
   1.3 mm thick coverage = 20 cm
What needs to be covered

Siemens protocol
160 images
1.3 mm thick
cover 20 cm

GE protocol
120 images
1.8 mm thick
cover 22 cm

Who gets a breast MRI?

From an expert panel on breast imaging
updated in November 2013
ACR appropriateness criteria for breast cancer screening

Mammography: Only method of screening for breast cancer shown to decrease mortality

<table>
<thead>
<tr>
<th>Annual mammogram starting at</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age 40 for the general population</td>
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ACR appropriateness criteria for breast cancer screening
(From an expert panel on breast imaging)

Annual mammogram starting at
1. Age 40 for the general population

ACR appropriateness criteria for breast cancer screening

Annual mammogram starting at
1. Age 40 for the general population
2. Age 25-30
   • for BRCA (breast cancer gene) carriers
   • Untested relatives of BRCA carriers
ACR appropriateness criteria for breast cancer screening

Annual mammogram for

3. Patients with a first degree relative with pre-menopausal breast cancer

**a first degree relative is a member of the family who shares about 50% of their genes with a particular member of the family: parents, offspring and siblings.

3. Patients with a first degree relative** with pre-menopausal breast cancer

- Mammo starting age 25-30
- Or 10 yrs before the age when the relative was first diagnosed, whichever is later
- Women with a lifetime risk of breast cancer ≥ 20% based on their family history
ACR appropriateness criteria for breast cancer screening

annual mammograms

3. Patients with a first degree relative with pre-menopausal breast cancer
   - Mammo starting age 25-30
   - Or 10 yrs before the age when the relative was first diagnosed, whichever is later
   - Women with a lifetime risk of breast cancer ≥ 20% based on their family history

4. For women who received mantle radiation between ages of 10-30, mammograms starting 8 yrs after radiation treatment but not before 25 yrs old.

ACR appropriateness criteria for breast cancer screening

5. Any age after biopsy proven:
   - Lobular Neoplasia
   - Atypical Ductal Hyperplasia (ADH)
   - Ductal Carcinoma in situ (DCIS)
   - Invasive breast Cancer

   The ACR notes that mammography alone does not perform as well in
   - women with genetic predisposition
   - women with dense breasts

ACR appropriateness criteria for breast cancer screening

- Breast MRI in high risk women has been shown to have a higher sensitivity than mammography
- The combination of mammography and breast MRI have a higher sensitivity (92.7%) than ultrasound and mammogram combined (52%)
- The ACR recommends MRI as supplemental screening in high risk women
appropriateness criteria for breast cancer screening

The American Cancer Society, The ACR and the Society of Breast Imaging recommend MRI screening on:

1. Women with BRCA gene mutations
2. Untested First Degree relatives of women with BRCA gene mutations
3. Women with lifetime risk ≥ 20%
4. Women who have received radiation treatment to the chest between the ages of 10-30 yrs old
5. Women with other genetic syndromes that increase the risk of breast cancer (i.e. Li-Fraumeny syndrome)

breast cancer risk models

- BRCA-PRO model – assesses probability that an individual carries the BRCA gene mutation

brca-pro model

- Evaluates family history and helps determine the likelihood of finding the BRCA 1 or BRCA 2 gene mutation in a family
- Can be used to determine if a patient will benefit from testing for the BRCA gene mutation ($3500)
- Model does not test or calculate risk based on nonhereditary factors
- This method is less accurate than other methods for breast cancer risk assessment
breast cancer risk models

- BRCA-PRO model – assesses probability that an individual carries the BRCA gene mutation
- Gail model – Designed by researchers at the National Cancer Institute, calculates risk within 5 yrs and within a lifetime. It is the basis for the Breast Cancer Risk Assessment tool from the National Cancer Institute

the gail model

estimates the chances of a woman of developing invasive breast cancer over specific periods of time

1. based on a statistical model by Dr Mitchell Gail from the NCI
2. woman’s personal history: number of biopsies and presence of atypical hyperplasia
3. Reproductive history: age at first menses, age at first live birth
4. Hx of breast ca among first degree relatives (mother, daughter, sister)

gail model

- focuses primarily on nonhereditary risk factors, with limited information on family history.
- It also compares the woman's risk calculation with the average risk for a woman of the same age.
- The Gail Model is an on-line quiz that has 13 questions and is interactive.
- Has been extensively tested for its validity, and has been validated for different populations
- Has not been validated for Hispanic populations yet
- Limited information on family history may underestimate risk
breast cancer risk models

- BRCA-PRO model – assesses probability that an individual carries the BRCA gene mutation
- Gail models – Designed by researchers at the National Cancer Institute, calculates risk within 5 yrs and within a lifetime. It is the basis for the Breast Cancer Risk Assessment tool from the National Cancer Institute
- Claus model - For individuals with no more than two first degree relatives or second degree relatives with breast cancer
- Tyrer-Cuzick model – estimates the likelihood that a person may be carrying the BRCA 1 or 2 mutations

claus model

- Incorporates paternal and maternal family history as well as family history of ovarian cancer
- Limited because it does not include risk factors other than family history
Tyrer-Cuzick model

- incorporates both genetic (3 generation pedigree) and nongenetic factors like:
  - Age
  - Age at first live birth
  - Age at menopause
  - Height and weight
  - Use of hormone replacement therapy
  - Comprehensive family history

breast cancer risk models

Other risk assessment models incorporating breast density have been developed but are not ready for clinical use.

In the future, additional models may be developed or refined to include such factors as breast density and other biomarkers.

From the National Cancer Institute, Dec., 2013

breast cancer risk main factors

1. being a woman
2. being 50 or older
3. carrying the BRCA 1 or 2 gene mutations
fluctuations in breast enhancement
From: Physiologic changes in breast magnetic resonance imaging during the menstrual cycle: perfusion imaging, signal enhancement, and influence of the T1 relaxation time of breast tissue. Delille, Slanetz, Yeh, Kopans, Garrido. Breast J. 2005 Jul-Aug;11(4):236-41

- No significant change in T1 relaxation time (pre-contrast) during the cycle
- Enhancement varied significantly during the menstrual cycle:
  - Low values of enhancement during the first half of the cycle and high values during the second half
  - Lowest values of enhancement were found during the proliferative phase (days 3-7)
  - Highest values were found during the secretory phase (days 21-27)

This paper concludes:
MRI should be performed during the first half of the menstrual cycle between day 3-14

ACR practice guidelines for the performance of contrast enhanced Magnetic Resonance Imaging (MRI) of the breast (revised in 2013)

The ACR recommends:
“...it is therefore recommended that breast MRI scans be performed during the second week of the menstrual cycle” (day 7-14)

(at Memorial Regional between day 7-10)
Days 1-5: 
Menstrual Phase

- The thick, hormone dependent functional layer of the endometrium detaches from the uterine wall
- Bleeding occurs for 3-5 days
- FSH and gonadotropins begin to rise
- Ovarian hormones at lowest levels

Days 6-14: 
Secretory (post-ovulatory) phase

- Endometrium’s basal layer rebuilds a new functional layer
- Rising estrogen levels
- Rising estrogen levels causes enlargement of the breast ducts
- Day 14: ovulation occurs after sudden release of luteinizing hormone from the pituitary

Days 15-28: 
secretory (post-ovulatory) phase

- Progesterone levels in blood rise
- Endometrium develops glands and arteries and becomes thick and spongy
- Increased progesterone causes enlargement of breast lobules (milk ducts)
- In the absence of implantation, menstruation occurs

what do we need?

Highly trained technologist

Technical Stuff

system
- magnet
- gradients
- coils
- software
- injector

Interpretation Stuff

Specialized radiologist
- CAD
**Technical Stuff**

**What are we looking for?**

1. Adequate S/N – not too grainy
2. Good spatial resolution:
   - ACR recommends
   - Slice thickness = 3mm or less
   - In-plane pixel size = 1 mm² or less
3. No artifacts
4. Bilateral imaging
5. Gadolinium enhancement
   - 0.1 mmole/Kg followed by at least 10 ml of saline
6. Kinetic information from pre and post contrast images separated by less than 4 min
7. Dedicated bilateral breast coil
Magnet

3T versus 1.5T

higher signal to noise (2x that of 1.5T)
better fat sat

Magnet

3T versus 1.5T

higher signal to noise (2x that of 1.5T)
better fat sat

best homogeneity, no dialectric effect

Magnet

Uniformity at 3 Tesla

B1 field maps in a conductive saline phantom (18 cm diameter)

### Magnet

<table>
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<tr>
<th>3T</th>
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<td>higher signal to noise (2x that of 1.5T)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>better fat sat</td>
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<td></td>
</tr>
<tr>
<td>possibility of improved resolution</td>
<td></td>
<td></td>
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** From: Contrast enhanced MR imaging of the breast at 3T and 1.5T in the same patients: Initial experience
Christiane Kuhl et al. Radiology, vol 239: Issue3, pgs.: 666-676

### Magnet

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at Memorial Regional Hospital 1.5T Siemens Avanto
with 16 channel breast coil voxel size is
.9 x .7 x 1.3 mm = voxel size of 0.8 mm³ for dynamics
.7 x .7 x .8 mm = voxel size of .3 mm³ for hi-res
Magnet

3T versus 1.5T

higher signal to noise (2x that of 1.5T)
better fat sat
posibility of improved resolution
longer T1 times, issues with enhancement

Spatial resolution

Spatial resolution is determined by the size of the voxel
Each pixel is configured by two sides:
  Phase and Frequency
Each voxel is configured by three sides:
  Phase, Frequency and Slice thickness
Note: the size of the pixel will determine in-plane resolution

Spatial resolution

Spatial resolution is determined by the size of the voxel
Each pixel is 2 mm x 2 mm
Each voxel is 2 mm x 2 mm x 4 mm
Matrix size = 8 x 8
FOV = 16 mm
Spatial resolution is determined by the size of the voxel. Each voxel size is calculated by pixel size x slice thickness or Pixel size(p) x pixel size(f) x slice thickness.

The volume of a box is calculated by multiplying three of its sides: Height x Length x Width.

**FORMULA STATION**

Pixel size = \( \frac{\text{FOV}}{\text{Matrix steps}} \)

**FORMULA STATION**

Pixel size = \( \frac{\text{FOV}}{\text{Matrix steps}} \)

FOV = 16 mm
MA = 8 by 8

Pixel size = \( \frac{16}{8} = 2 \text{ mm} \)
how to increase spatial resolution

- Select a thin slice
- Select a large (fine) matrix increase matrix size
- Select a small FOV
- Select rectangular FOV

ACR requirements

For pre and post contrast T1 weighted sequences

Slice Thickness \( \leq 3 \text{mm} \)
Gap = 0
In plane pixel dimension \( \leq 1 \text{mm} \)

Technical Stuff gradients

- Gradient Amplitude (strength) –
  Higher gradient amplitudes are needed for small FOV’s and thin slices
### Technical Stuff

#### gradients

- **Gradient Amplitude** (strength)
- **Gradient rise time** – time that it takes for the gradients to reach its maximum amplitude (maximum strength)
  - faster gradients will give you shorter imaging times
- **Slew rate** – rate of change of strength of the gradient over distance
  - 70 mT/m/s
  - High slew rates allow for short TR, short TE and reduced echo spacing
- **Duty cycle** – percent of the time the gradient is allowed to be at its highest amplitude
Technological Stuff
Parallel Imaging

1. SENSE – Sensitivity Encoding
2. ASSET – Array Spatial and Sensitivity Encoding Technique
3. SPEEDER
4. SMASH – Simultaneous Acquisition with Spatial Harmonics
5. GRAPPA – Generalized Autocalibrating Partially Parallel Algorithm
6. I PAT – Integrated Parallel Acquisition Technology

The strength of the signal received by different coils can be used for spatial localization.

When the acceleration factor “R” = 2, there is a 50% reduction in time.

Parallel Imaging allows for faster scans but reduces S/N directly proportional to the acceleration factor.

An acceleration factor R=2 reduces S/N by √2.

More coil elements, higher acceleration factors are possible.

Phase array body coil with multiple elements.
Technical Stuff
high receiver bandwidth

- Higher SNR
- Less noise
- Smaller minimal FOV

Lower BW

- Lower SNR
- More chemical shift
- Longer echo spacing
- Increased susceptibility artifacts
- More metal artifacts

Higher BW

- More chemical shift
- Shorter echo spacing
- Reduced susceptibility artifacts
- Fewer metal artifacts

From Graessner, J., Siemens Magnetom Flash

Technical Stuff protocol

- T2 weighted or bright fluid sequence (STIR)
- Multiphase T1 weighted sequence pre contrast
- Early phase and delayed phase sequences
- Some protocols include a coronal STIR of the chest

<table>
<thead>
<tr>
<th>GE</th>
<th>VIBRANT – Volume Image Breast Assessment</th>
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<tbody>
<tr>
<td>PHILLIPS</td>
<td>THIVE – T1 High Res Isotropic Vol Excitation</td>
</tr>
<tr>
<td>SIEMENS</td>
<td>DYN VIEWS, VIBES</td>
</tr>
<tr>
<td>AURORA</td>
<td>RODEO</td>
</tr>
<tr>
<td>HITACHI</td>
<td>TIGRE</td>
</tr>
<tr>
<td>TOSHIBA</td>
<td>RADIANCE</td>
</tr>
</tbody>
</table>
Technical Stuff
coils

Match coil channels with your system's receiver channels

- If your coil has more channels than your system, it will produce shaded images
- More coil channels will allow you to have better S/N and greater parallel imaging factors
- Try to have coils with biopsy capability

injector

1. Dual head injector
2. Constant rate of injection and accurate timing
3. Saline flush maintains contrast in a bolus

NOTE: ACR manual on contrast media suggests that injector should be pointing down after loading to avoid air emboli
Injector

Technique

To avoid potential complications, the patient’s full cooperation should be obtained whenever possible. Communication with the patient before the examination and during the injection may reduce the risk of contrast media extravasation. If the patient reports pain or the sensation of burning at the injection site, injection should be discontinued.

 Intravenous contrast media should be administered by power injectors through a flexible plastic cannula. Use of metal needles for power injection should be avoided. In addition, the flow rate should be appropriate for the gauge of the catheter used. Although 22-gauge catheters may be able to tolerate flow rates up to 3 mL/sec, a 20-gauge or larger catheter is preferable for flow rates of 3 mL/sec or higher. An arteriologist or large femoral vein is the preferred venous access site for power injectors. If a femoral vein (e.g., hand or wrist) venous site is used, a flow rate of no greater than 1.5 mL/sec may be necessary.

Careful preparation of the power injection apparatus is essential to minimize the risk of contrast medium extravasation or air embolism. Standard procedures should be used to control the pressure and pressure settings of the injectors. After which the injectors should be connected to the imaging device. Before inflating the injection site or the venous access site, the flow rate of the injectors should be checked for venous backflow. If backflow is not obtained, the catheter may need adjustment, and a visual test for air embolism may be performed. If a venous backflow is obtained, the power injection and flow rate should be reduced to allow adequate blood flow without tension on the intravenous line.

Kinetics

KINETICS

CAD
KINETICS

- Kinetic evaluation only
- Looks at rates of enhancement, does not diagnose
- Has motion correction – MOCO
- Does MPR, MIP automatically when it recognizes the image descriptions
- In CAD red is bad - washout

From: Radiology Assistant, Glassman and Hazewinkel

CAD computer aided detection

morphology of enhancing lesions

- FOCUS
- MASSES
- NON-MASS ENHANCEMENT

From: Radiology Assistant, Glassman and Hazewinkel
morbidity of enhancing lesions

FOCUS – too small to be characterized

From: Radiology Assistant, Glassman and Hazewinkel

morbidity of enhancing lesions

Masses

Shapes

- Round
- Oval
- Lobulated
- Irregular

Margins

- Smooth
- Irregular
- Spiculated

From: Radiology Assistant, Glassman and Hazewinkel

morbidity of enhancing lesions

Non-mass like enhancement

- Linear
- Ductal
- Segmental
- Clumped
- Etc. (diffused, regional)

From: Radiology Assistant, Glassman and Hazewinkel
Internal enhancement characteristics of breast lesions

- Mass
  - Internal Enhancement
    - Homogeneous
    - Heterogeneous
    - Rim
    - Dark internal septation
    - Enhancing internal septation
    - Central enhancement

- Non-mass-like enhancement
  - Internal Enhancement
    - Homogeneous
    - Heterogeneous
    - Stippled/punctate
    - Clumped
    - Reticular/linear

From: nih.gov

morphology of enhancing lesions

Irregular mass: proved to be an angiosarcoma

From: Radiology Assistant, Glassman and Hazewinkel

morphology of enhancing lesions

A. Oval – fibroadenoma
B. Lobulated – fibroadenoma
C. Smooth – Epithelial Inclusion cyst

From: Radiology Assistant, Glassman and Hazewinkel
Spiculated mass has an 80% chance of being malignant.

From: Radiology Assistant, Glassman and Hazewinkel

MRI lexicon: morphology of contrast enhanced breast lesions by Steven Halls, MD

positioning

arms up or arms down

From: MRI lexicon: morphology of contrast enhanced breast lesions by Steven Halls, MD
Centering properly avoids artifacts.


Positioning

Try laying the patient on a pillow case and use the pillow case to pull the inferior bulge down and away from the coil.

Decoupling occurs because of uneven positioning within the coil resulting in poor fat saturation.

This article proposes padding under the sternum to lift the breast away from the coil.

The breast takes the shape of the coil.

missed cancer
pseudo cancer

64 y/o asymptomatic patient for high risk screening shows asymmetric breast with skin thickening and a possible mass

Patient returned for proper positioning

chemical shift peaks

center frequency  
fat frequency

chemical shift peaks

silicon peak
**Chemical shift peaks**

Post dynamic 3D T1
(9 x 7 x 1.3 mm)

---

**Chemical shift peaks**

STIR SEQUENCE
TI = 160 msec suppresses fat
+
A saturation pulse to suppress water

Sagittal water sat image

---

**Breast with two different implants**

STIR seq with silicone suppression
Center on silicone peak and pick the water saturation pulse

Silicone

STIR seq with water sat pulse
Breast with two different implants

How many peaks...?

Patient with silicone injections
How many peaks on this one?

Breast biopsy

Lesion must be within the grid in all planes
Before injecting make sure that lesion can be localized (targeted)
Breast biopsy

If lesion is posterior and medial try positioning with the ipsilateral arm down

Use good compression

Breast biopsy

Push implant out of the way of the biopsy

Breast biopsy
Breast biopsy

Breast Spectroscopy
Syngo Grace by Sheila Christ

1A. Spectrum shows a high choline peak prior to chemotherapy.

Water peak at 4.7 ppm
Choline metabolite in healthy breast is almost negligible

1B. Choline signal appears reduced after second cycle of chemotherapy.
Choline levels may be visible in the lactating breast
Breast Spectroscopy

Syngo Grace by Sheila Christ

- tCho concentration can be used as an indicator for predicting clinical response to chemo.

Images courtesy of Prof. C. J. Vogl, University of Frankfurt/Main, Germany

scripting

- Scripts help us create a predictable positive experience providing a consistent level of great service is difficult.

- Scripts can be linked to department goals incorporate language that the patient will see in the satisfaction surveys.

- Use key words that reflect the satisfaction survey. Use the key words but own your script so that you feel comfortable using it.

Use AIDET:
- Acknowledge
- Introduce
- Duration
- Explanation
- Thank
scripting

use key words at key moments

C. YOUR TEST OR TREATMENT

1. Friendliness courtesy of the staff who provided your test or treatment.
2. Explanations from the staff about what would happen during your test or treatment.
3. Skill of the staff who provided your test or treatment.
4. Staff's concern for your comfort.
5. Staff's concern for your questions and worries.

"These pads are for your comfort."
"Before I start let me know if you are as comfortable as possible."
"I'll be talking to you between scans please let me know if you have any questions or concerns."
"Mary will be starting your IV, she is very skilled."

It is preferable that you avoid talking during the exam to avoid motion... do you have any questions or concerns before we start?"
scripting

D. PERSONAL ISSUES

1. Our concern for your privacy
2. Our sensitivity to your needs
3. Response to concerns/complaints made during your visit
4. Your confidence that staff provided care in a safe and secure manner
5. How well you were informed of pain control options (if applicable)

“I’m going to close the door for your privacy”
“I’m flushing the IV for your safety”
“I’m scanning you with the metal detector for your safety”

“If you have pain we can reposition the padding so that we can try to control the pain”

scripting

B. FACILITY

1. Comfort of the waiting area
2. Ease of finding your way around
3. Cleanliness of the facility

“Let me help you find your way to the elevator”

“If you are cold, we have blankets so that you can be comfortable in the waiting area”

scripting

A. REGISTRATION

1. Helpfulness of the person at the registration desk
2. Ease of the registration process
3. Waiting time in registration

Some things may be out of your control but service recovery is your responsibility
Scripting for service recovery

A. REGISTRATION

1. Helpfulness of the person at the registration desk
2. Ease of the registration process
3. Waiting time in registration

1. Address the customer in a calm manner

2. State your positive intention: "we will try to see you as soon as we possibly can", "in the next 20 mins"…

3. Express empathy: "I can imagine as you wait you may feel impatient"

4. Acknowledge and apologize (even if it is not your fault)

5. Give the reason for the wait in a way that builds customer confidence:
   - Build their confidence “we give each patient the quality and attention they deserve”
   - Don’t erode their confidence, don’t say for example: “we are short of people today”

6. Offer options for making the time go faster

7. Provide frequent updates

8. Say thanks for waiting