Magnetic Resonance Imaging of the Female Breast

Its Role, Indication, Technique & Future.
Introduction

Breast cancer is the most common cancer among women in the US. The incidence has been rising for the past two decades, while mortality has remained relatively stable since the 1950s. Much of the increase over the past 15 years is associated with increased detection from screening, but screening alone does not explain all of this increase. Early detection and diagnosis is still essential due to planned BCT (breast conserving therapy).
Epidemiology - Incidence

The age-adjusted incidence shows that white, Hawaiian, and black women have the highest rates. The lowest rates are among Korean, American Indian, and Vietnamese women. The incidence rate for white non-Hispanic women is four times as high as that for the lowest group (Korean women).
Epidemiology - Mortality

Mortality is much lower than incidence for breast cancer, ranging from just 15% for Japanese women to 33% for black women. Racial/ethnic patterns of mortality differ slightly from those observed for incidence. The highest age-adjusted mortality occurs among black women, followed by white, and Hawaiian women. The higher mortality among black women is related to the fact that a larger percentage are diagnosed at a later stage.
Risk Factors

- early age at onset of menarche
- late age at onset of menopause
- first full-term pregnancy after age 30
- a history of pre-menopausal breast cancer for mother and a sister
- a personal history of breast cancer or of benign proliferative breast disease
- Obesity, nulliparity and urban residence are also associated with increased risk
The Four Pillars of Diagnosis

Clinical or Self Examination (PE)

Mammography (MG)

Ultrasound (US)

Magnetic Resonance Imaging (MRI)
## Primary Diagnostic

<table>
<thead>
<tr>
<th></th>
<th>MG</th>
<th>(US on dense breast ?)</th>
<th>MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Screening</strong></td>
<td>MG</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Multicentricity</strong></td>
<td>MG /</td>
<td>magnified-MG</td>
<td></td>
</tr>
<tr>
<td><strong>HR-US</strong></td>
<td></td>
<td></td>
<td>MRI</td>
</tr>
<tr>
<td></td>
<td>on calcifications</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Palpable Findings</strong></td>
<td>MG</td>
<td>US</td>
<td>(MRI ?)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intervention</strong></td>
<td>US</td>
<td>MG-Stereotaxy</td>
<td>(MRI ?)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HR-US = high-resolution ultrasound  
MRI = Magnetic Resonance Imaging  

- MG = Mammography  
- CT = Computer tomography

- not compulsive  
- equivalent exam  
- not routine diagnostic  
- equivalent, but not routine
## Recurrence Diagnostic

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Imaging 1</th>
<th>Imaging 2</th>
<th>Imaging 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BCT</strong></td>
<td>US</td>
<td>↔</td>
<td>MG</td>
</tr>
<tr>
<td><strong>Implant</strong></td>
<td>US</td>
<td>→</td>
<td>MG</td>
</tr>
<tr>
<td><strong>Thoracic wall</strong></td>
<td>US</td>
<td>→</td>
<td>MRI / CT</td>
</tr>
<tr>
<td><strong>Intervention</strong></td>
<td>US</td>
<td>→</td>
<td>MG-Stereotaxy</td>
</tr>
</tbody>
</table>

**Abbreviations:**  
HR-US = high-resolution ultrasound  
MG = Mammography  
MRI = Magnetic Resonance Imaging  
CT = Computer tomography  
BCT = breast conserving therapy  

**Notes:**  
→ not compulsory  
↔ equivalent exam  
↔ equivalent, but not routine
Indication for MR-Mammography

- DDx scar versus tumor (recurrence) after BCT and irradiation
- Pre-/aftercare on patients with inlay reconstructed or augmented breasts
- Clarification of nondistinctive MGx, USx and / or clinical findings
- Help on MGx with dense breast + concomitant increased cancer risk
- CUP (carcinoma of unknown primary) or axillary lymphnodes (with positive hormone receptors), if conventional imaging is not significant
- In institutes, who can offer a (MR guided) needle marking :
  As pre-op staging on clinical resp. conventional-radiologic shown breast cancer, before planned BCT for exclusion of multicentric or contralateral manifestation.
Possible further Indications

- Monitoring of a primary / neo-adjuvant chemotherapy / radio-chemotherapy
- Control of high risk patients with hereditary breast cancer
- Comedo calcification in mammogram

(Keep in mind: microcalcifications are per se not MRI indication !!)
MR-Mammography

- *Problems*

  - No defined standard technique
  - No consensus quantifying clinically important enhancement
  - No standard interpretation criteria
  - No clearly defined indications
  - Costly examination
History of MR-Mammography

- 1946 G. M. Purcell and F. Bloch found the magnetic resonance
- 1971 Damadian indicated the possible examination of the female breast
- 1979 Mansfield et al. published the first pictures of breast cancer (T1 and T2 images)
- Introduction of
  - Faster sequences
  - Use of paramagnetic contrast agents
  - Dedicated breast coils = increased SNR (signal-to-noise-ratio)
  - Dynamic examination with increased spatial resolution possible
- Two groups dominated the later years
  - „2-D“-school of Kaiser favoring high temporal resolution
  - „3-D“-school of Heywang favoring the high-spatial resolution
- Today: 3D Imaging is “standard” because of faster sequences
Hardware

High-field strength (1.0 – 1.5 Tesla) necessary, resulting in:

- a higher signal-to-noise-ratio
- shorter acquisition time
- better separation of fat and water peaks
- better contrast characteristics

(T1 time increase)
Breast Coils

- Patient is lying in a prone position
- Dedicated breast surface coil with single or bilateral breast design
- Mostly phased-array bilateral-breast coils
- Mostly solenoid or solenoid like
- Alternative: two plates each of which contains a two-coil phased array provides better SNR
- also coils for MR-guided breast biopsy available
Imaging Protocols

- DD static and dynamic MRI (T2-weighted images vs. fat-sat fast imaging)
- DD 2D vs. 3D Imaging
- DD implants and no implant (chemical shift imaging)
- DD coronal and axial imaging
- MIP (maximum intensity projection)
- MPR (multiplanar reconstruction)
Static MR-Mammography

- DD static and dynamic MRI (T2-weighted images vs. fat-sat fast imaging)
T1 Short Tau Inversion Recovery Measurement

The STIR (Short Tau Inversion Recovery Measurement) is often used as a high-resolution sequence for detection of lesions (in order to define the region for dynamic imaging).

The choice of TR (repetition time) and TE (echo time) defines, if a sequence is T1- or T2-weighted.

A short TR (< 800 ms) and a short TE (< 30 ms) enables the examiner to distinguish tissue due to its T1-value.
T2-weighted Spin Echo Sequences

T2-weighted sequences are called SE- or TSE (= turbo spin echo).

They are used for static examination of water containing and oedematous structures.

DDx of smooth defined masses like:

- Cysts
- Myxoid fibroadenomas  
  (strong enhancement due to small fibrotic fraction)
- true carcinomas  
  (weak parenchyma-like enhancement)
Silicone Imaging

In visualizing silicone we use the shortening of T1 time on account of its stronger magnetic moment.

The relative resonance frequencies of water, fat and silicone are different (chemical shift). Therefore each can selectively be suppressed.

By combining of fat- and water-suppression, silicone can be visualized for its own.

In double-lumen implants you can distinguish between the saline and the silicone part of the inlay.

We use especially Inversion-Recovery-Sequences for suppression of the different frequencies.
Dynamic MR-Mammography

- DD static and dynamic MRI

(T2-weighted images vs. fat-saturated fast imaging)
Use of Paramagnetic Contrast Agents

Gd-DTPA (Magnevist®) leads to a shortening of T1- and T2-relaxation time whereas the emphasis is on T1 shortening.

The unconjugated electron of gadolinium has a 1000 times stronger magnetic moment as a proton. On account of its toxicity Gadolinium$^{3+}$ is complexed with DTPA, DOTA or EDTA. Therefore the increased water solubility and osmolarity improves the renal elimination.
Two-Compartment-Model

The amount of measured contrast agent depends on the “wash-in” into the extra-cellular volume and vice versa. The duration of enhancement is due to the size and physical nature of the extra-cellular volume.

Knop developed a model for the distribution and enhancement of the contrast agent in the breast.
Curve Analysis - Plateau

Rather malignant enhancement
Curve Analysis - Cumulation

Rather benign enhancement
Postprocessing (MPR)

With a Gradient echo sequence we achieve a 3D volume.

For further post-processing a second phase encoding gradient is generated in the direction of the slices. We get a “sliced” volume and are enabled to generate any view we want.

This technique is called multiplanar reconstruction.
Postprocessing (MIP)

The post-processing algorithm selects the largest value (maximum intensity) and provides a set of viewing angles through the imaging volume. Only the enhancing structures like vessels and the tumor are visualized. Therefore it is useful in diagnosis of the blood supply of a mass.
Artifacts as a Pitfall

Patient induced artifacts
  movement
  breathing / peristaltic
  vessel pulsation / heart beat
  after interventions / irradiation
  induced by certain meds (eg. hormone)
  by inter- and intra-individual fluctuations

Technique induced artifacts
  Chemical shift artifact
  wrap around
  magnetic susceptibility artifact
  GIBBS-artifact or mutilation
  coil dependent artifact

By wrong post-processing induced artifacts
  wrong placed ROI (region of interest)
  wrong adjustment

Induced by examiner
  failed contrast agent application
Our Patient – History & Clinical Examination

Patient M. L., 51 year old female.

History of breast biopsy right upper outer quadrant with negative pathology. She is on Tamoxifen for ADH (atypical ductal hyperplasia).

On clinical examination in follow up for bilateral breast masses her physician palpated lumps in the breasts bilaterally, two on the right and one on the left, not felt by patient.

Her breast exam reveals no skin changes in 4 positions bilaterally. There is no adenopathy in the supraclavicular, infraclavicular, cervical or axillary regions bilaterally. There is no nipple discharge or retraction bilaterally. There are well healed scars, the breasts are small and dense.
Our Patient - Mammography

CC and MLO views of both breasts show heterogeneously dense parenchymal tissue reducing mammographic sensitivity, though no dominant mass is seen. Minimal architectural distortion in the right breast upper-outer quadrant is present, reflecting prior surgical sampling of microcalcifications. Scattered and occasionally loosely grouped microcalcifications in both breasts are stable. There has been no interval development of any suspicious clustering of microcalcifications.

BIRADS category 2 - benign findings.
Bilateral benign-appearing *hypoechoic nodules on the right* (nonpalpable 10 x 12 x 5 mm ovoid hypoechoic) and on the left (7 x 5 x 6 mm ovoid hypoechoic nodule with no internal vascularity). This left nodule is in the area of palpable abnormality, although the palpable abnormality to the examiner is larger than this nodule. No other discrete cystic or solid lesions are seen.

Neither of these nodules clearly correspond to any of the three palpable abnormalities.
Our Patient – MRI Report

INDICATION:
1 cm oval mass in right periareolar region, patient with h/o atypical lobular hyperplasia. Discrepancy between US, MG and physical exam.

TECHNIQUE:
Multi-sequence, multiplanar MR imaging of the right breast was performed, including STIR, high-resolution T1 and dynamic post-gadolinium VIBE sequences.

FINDINGS:
Two well circumscribed nodules are visualized in the right breast. In the central right breast, 4 cm deep to the nipple, there is a 9 x 6 mm well-circumscribed enhancing nodule, which demonstrates gradual enhancement most characteristic of a benign lesion. This lesion is in the posterior third of the breast, approximately 1.4 cm from the chest wall and 2.1 cm from the lateral skin surface. There is an additional small enhancing well-circumscribed nodule in the upper medial aspect of the breast measuring approximately 5 x 3 mm. This nodule also demonstrates gradual enhancement, characteristic of a benign lesion. No suspicious masses are identified in the right breast.

IMPRESSION:
No MR finding to correspond to the nodule seen on the sonogram of the right breast. There are two well circumscribed enhancing nodules within the right breast with benign features. There is no suspicious right breast finding.
Static Imaging

STIR (Short tau inversion recovery)
High resolution Imaging

Flash 3D Vibe

Flash 3D HR
Dynamic Imaging

Post contrast with fat-supression.

Flash 3D HR
Postprocessing I

Postprocessing with curve generation and false color imaging.
Postprocessing II

Reformatted image and subtraction image.
Summary

Although there are no standards defined yet, MR-Mammography is a method to help detect, diagnose and stage breast cancer with high sensitivity and specificity.

It also offers clinically important information, that in some cases can not be obtained with other imaging methods like mammography or ultrasound.

Further developments will enable the examiner to image breast cancer with high-resolution sequences and even perform MR-guided biopsies.
References

1. Susan G. Orel, Mitchell D. Schnall
   MR Imaging of the Breast for the Detection, Diagnosis and Staging of Breast Cancer
   Radiology 2001; 220: 13-30

2. Miller BA, Kolonel LN, Bernstein L, Young, Jr. JL, Swanson GM, West D, Key CR,
   Liff JM, Glover
   CS, Alexander GA, et al. (eds).
   Racial/Ethnic Patterns of Cancer in the United States 1988-1992,

3. Stuart S. Kaplan, MD
   Clinical Utility of Bilateral Whole-Breast US in the Evaluation of Women with Dense
   Breast Tissue
   Radiology 2001; 221:641–649
Acknowledgements

I would like to thank the following persons who helped me with their knowledge and advise.

Gillian Lieberman, MD
Neil Rofsky, MD
Haldon Bryer, MD
Ivan Pedrosa, MD
Maria-Candida Albano, MD
Joachim Teubner