Learning Objectives

- Image quality and dose characteristics of
  - Stereotactic Breast Biopsy (SBB) systems
  - Screen-Film and Full-Field Digital Mammography systems

Outline

- Introduction
- Image quality characteristics of:
  - Stereotactic Breast Biopsy (SBB) systems
  - Screen-Film mammography (SFM) systems
  - Full-field digital mammography (FFDM) systems
- Patient dose: Average Glandular Dose (AGD)
- Summary

Introduction

- Mammograms show abnormalities such as a suspicious solid mass, microcalcification clusters etc.
- Biopsy done to determine the abnormalities are benign or malignant
  - Reduces number of benign open surgeries
- Types of breast biopsy:
  - Fine Needle Aspirations (FNA)
  - Vacuum Assisted (VA)
  - Core Needle (CN)
  - Open Surgical

Introduction

- Normal mammogram
- Benign cyst (not cancer)
- Cancer

http://www.cancer.gov/cancertopics/screening/understanding-breast-changes/page6
Introduction

- Accuracy of localization of the lesion is critical in biopsy procedures
- It depends on:
  - Accuracy of the equipment used
  - Sample volume size
  - Skill of the clinician

Image-guided Biopsy

- Grid coordinate system
  - Uses dedicated mammography equipment
  - Only 2D localization – lack of depth accuracy
- Ultrasound-guided biopsy systems
  - Lack of visualization and accuracy of localization
- Stereotactic breast biopsy systems (SBB)

Stereotactic Breast Biopsy (SBB) Systems

- Localization in 3D and accurate to within 1mm
- Less dependent on operator skills compared to other methods
- Limitations include localization of lesions:
  - Widely scattered throughout the breast
  - Near the chest wall or high in axilla
  - In very thin breasts

Stereotactic Breast Biopsy (SBB) Systems

- Based on a “zero-degree” scout and two radiographs 30 degrees apart (±15 deg)

Carr et al., Radiographics, 2001; 21:463-473

www.Radiologictechnology.org
## Requirements

<table>
<thead>
<tr>
<th>Mammography</th>
<th>SBB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection and characterization of abnormalities</td>
<td>Localization, targeting and sampling the abnormalities</td>
</tr>
</tbody>
</table>

## System Design

### Mammography
- Mo/Mo, Mo/Rh, Rh/Rh, W/Rh, W/Ag
- Large target angle
- 0.1 and 0.3 mm focal spot
- Grid for scatter removal (contact mode)
- Strong compression
- Not much geometric blur in contact mode
- SID ~68 cm

### SBB (prone systems)
- Mo/Mo and Mo/Rh
- Steep target angle
- 0.25 mm focal spot
- Air gap for scatter removal
- Light Compression
- Possible high geometric blur
- SID ~88 cm

### System Design

#### Mammography
- 18 cm x 24 cm and 24 cm x 30 cm FOV
- Film screen, direct and indirect flat-panel receptors
- 100 micron pixel size (digital systems)

#### SBB (prone systems)
- 5 cm x 5 cm FOV
- CCD-based lens-coupled or fiber-optic coupled receptors
- 50 micron effective pixel size

### Digital Receptors

#### Indirect Flat Panel

#### Direct Flat Panel

### Digital Receptors

#### CCD Detectors

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**System Design**

**Side View**
- Focal Spot X-ray Tube
- Small area Collimator
- Compressed Breast
- Phosphor
- Fiber Optic
- CCD

**Front View**
- DMA
- A/D

Optical coupling/mirror system
Light reflection from phosphor

Image courtesy R. J. Pizzutiello

**Side View**
- Focal Spot X-ray Tube
- Small area Collimator
- Compressed Breast
- Phosphor
- Fiber Optic
- CCD

**Front View**
- DMA
- A/D

2:1 fiber optic taper demagnification
Light transmission through phosphor

Image courtesy R. J. Pizzutiello

**Type of SBB systems**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Prone Systems</th>
<th>Add-on Upright Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost and space</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Less Patient fatigue and motion</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Less Patient fear</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>No patient weight issue</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Better for handicapped patients</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Access to the breast</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Stroke margin safety</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Overall imaging performance</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

**Outline**

- **Introduction**
  - Image quality characteristics of:
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**Image Quality Characteristics**

- Contrast
- Noise
- Blur
- Artifact

**Factors Affecting Image Quality**

- Target/Filter
- Digital Image Display
- Image Receptor
- Image Processing
- Scatter
Image Quality Characteristics

Screen-film systems

Image Quality Characteristics – Contrast

Screen-film systems

Digital receptors

Dynamic range depends upon bit depth

Exposure

Pixel Value

4096

Image Quality Characteristics – Contrast

Image Quality Characteristics – Contrast

• Image processing
• Digital displays
• Window width and level functions

Image Quality Characteristics – Blur

• Geometric blur
  – Higher in SBB system compared to mammography systems
    • Increased mag due to air gap
    • No compression in the "open" part of the compression paddle
• Patient motion blur
  – SBB procedures take significantly more time compared to typical mammography procedures
**Image Quality Characteristics – Blur**

- Image receptor blur
  - SBB: 50 micron pixel (7-10 lp/mm in 1024x1024 mode)
  - Screen-film: grain size dependent (15-20 lp/mm)
  - Digital flat panel: approx. 100 micron pixel (8-10 lp/mm)
- Matrix size
  - 512 x 512 has less resolution than 1024 x 1024

**Image Quality Characteristics – Noise**

- Electronic “dark” noise for digital systems
- Speed is an issue for screen-film systems
  - eg. Kodak’s dual emulsion screen-film system
- Technique factors
Image Quality Characteristics

- Contrast
- Artifacts
- Blur
- Noise

Image Quality Characteristics – Artifacts

- Dead pixel
- Read-out failure

- Ghosting

- Dust

- Gridlines

- Patient accessories

Geiser et al., American Journal of Roentgenology 2011 197:6
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Average Glandular Dose (AGD)

- Dose index to estimate average dose to the glandular tissue just like CTDI is in CT
- Displayed on the units and calculated periodically
- “Standard” breast (4.2 cm compressed thickness and 50% Fatty and 50% Glandular composition) equivalent phantom

Factors Affecting AGD

- Dose
- Spectrum
- Technique
- Repeat/Retake
- Breast Density
- Breast Thickness

Average Glandular Dose (AGD)

- Typical doses for one cc view
  - SF systems – 180 – 250 mrad
  - Digital systems – 100 – 190 mrad
- Use of AEC and proper technique chart along with less repeats will minimize patient dose

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Summary

- SBB systems have different requirements compared to mammography systems which leads to unique system design
- Image quality characteristics were reviewed
- Factors affecting dose were reviewed

Future?

<table>
<thead>
<tr>
<th></th>
<th>Screen-Film</th>
<th>SBB (Prone systems)</th>
<th>FFDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blur</td>
<td>15-20 lp/mm</td>
<td>7-10 lp/mm [1024 mode]</td>
<td>8-10 lp/mm (contact mode)</td>
</tr>
<tr>
<td>Contrast</td>
<td></td>
<td></td>
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<tr>
<td>Display Viewbox</td>
<td>CRT: 480x640, 0.4 mm x 0.4 mm pixel pitch</td>
<td>Flatpanel/LCD: 2560 x 2048 (5MP), 0.165 mm x 0.165 mm pixel pitch, 850:1 contrast ratio</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flatpanel/LCD: 1280x1024 (1.3 MP), 0.285 mm x 0.285 mm pixel pitch, 550:1 contrast ratio</td>
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</tbody>
</table>

Future?