Mammography: Fundamental Principles, Equipment Design & Siting

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Disclosures

No disclosures
Educational Objectives

- Understand the physics of digital detector technology
- Recognize that vendors use varying detector technology in FFDM systems
- Appreciate the advantages and disadvantages of digital mammography systems
- Radiation Dose in FFDM systems
- Economics of FFDM systems
**Full-Field Digital Mammography (FFDM) versus Screen-Film Mammography (SFM)**

- Wide dynamic range (1000:1) compared with SFM (40:1)
- Dynamic image manipulation
- Ability to post-process
- Soft-copy read accompanied by computer-aided-diagnosis (CAD)
- 3D imaging
**FFDM versus SFM**

**Digital vs. Analog**

**SF Mammography**
- **Recording**: Inherent to Film/Screen
- **Display**: Fixed Light Box
- **Archival**: Film Library

**FFDM**
- **Recording**: Detector Class
  - System Configuration
  - Appropriate Technique (COMPLEX)
- **Display**: Image processing
  - Monitor calibration, read conditions
  - WW/WL / Magnification / ROIs
- **Archival**: Storage and transmission (compression)
  - User Interface: Hanging protocols
  - Tele-radiology

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All-in-one offers simplicity, but inflexibility…

Allows individual optimization of each process, but more opportunity for mistakes
**SFM vs. FFDM**

**SFM**: Half mAs, Automatic exposure control, Double mAs

**FFDM**: Same technique factors as SFM, W/L adjusted

Radiographics 2004:24,1750
**SFM vs. FFDM**

Radiographics 2004:24,1751
Technologies for FFDM

c.f: RSNA/AAPM Web module on Digital imaging
Technologies for FFDM - Indirect Capture

- A scintillator such as cesium iodide (CsI) absorbs x-rays and generates a light scintillation
- Detected by an array of photodiodes or charge-coupled devices (CCDs)
- Resolution degradation

[c.f: Bushberg, Third edition, pg. 266]
X-ray photons are captured by a photoconductor such as amorphous selenium (a-Se), which converts the absorbed x-rays directly into a electron-hole pair.

Spatial resolution limited to pixel size.

c.f: Bushberg, Third edition, pg. 266
Vendor Approaches - FFDM systems

- **Indirect**
  - A single flat-panel scintillator and an amorphous silicon (a-Si) diode array – **GE**
  - Slot scanning with scintillators and CCD arrays – **Fischer Imaging, not commercially available now**
  - Photostimulable phosphor plates - **Fuji**

- **Direct**
  - A flat-panel amorphous selenium (a-Se) array – **Hologic, Siemens**
  - A dual-layer a-Se system using direct optical switching technology - **Fuji Aspire HD**
FDA and Digital Mammography

- FDA Office of Device Evaluation
- Clears FFDM for sale in US
- Approves monitors and printers for sale in US
- FDA Office of Communication, Education and Radiation Programs
- Writes and enforces MQSA regulations
- Issues MQSA certificates
FDA and Digital Mammography

- FDA approved, cleared, or accepted the following FFDM for use in mammography facilities as indicated by date:
  - Konica Minolta Xpress CR System on 12/23/11
  - Agfa CR System on 12/22/11
  - Fuji Aspire CR System on 12/8/11
  - Giotto Image 3D-3DL FFDM System on 10/27/11
  - Fuji Aspire HD FFDM System on 9/1/11
  - GE Senographe Care FFDM System on 10/7/11
  - Planmed Nuance Excel FFDM System on 9/23/11
  - Planmed Nuance FFDM System on 9/23/11
FDA and Digital Mammography

- Siemens Mammomat Inspiration Pure FFDM System on 8/16/11
- Hologic Selenia Encore FFDM System on 6/15/11
- Philips (Sectra) MicroDose L30 FFDM System on 4/28/11
- Siemens Mammomat Inspiration FFDM System on 2/11/11
- Hologic Selenia Dimensions 2D FFDM System on 2/11/09
- Hologic Selenia S FFDM System on 2/11/09
- Siemens Mammomat Novation S FFDM System on 2/11/09
- Hologic Selenia FFDM System with a Tungsten target in 11/2007
- Fuji CR Mammography on 07/10/06
FDA and Digital Mammography

- GE Senographe Essential FFDM System on 04/11/06
- Siemens Mammomat Novation DR FFDM System on 08/20/04
- GE Senographe DS FFDM System on 02/19/04
- Lorad/Hologic Selenia FFDM System on 10/2/02
- Lorad Digital Breast Imager FFDM System on 03/15/02
- Fischer Imaging SenoScan FFDM System on 09/25/01
- GE Senographe 2000D FFDM System on 01/28/00
MQSA Scorecard

- Certification statistics, as of June 1, 2012
- Total certified facilities / Total accredited units
  - 8,626 / 12,367
- Certified facilities with FFDM units / Accredited FFDM units
  - 7,313 / 10,639
- 85% certified facilities with FFDM units
- 86% accredited FFDM units

http://www.fda.gov/Radiation-EmittingProducts/MammographyQualityStandardsActandProgram/FacilityScorecard/ucm113858.htm
Technologies for FFDM – Indirect Capture

GE

- In this system, the digital detector array is constructed from an a-Si thin-film transistor (TFT) matrix deposited on a glass substrate
- The CsI scintillator is deposited on the a-Si detector
- Each light-sensitive diode element is connected by TFTs
- To a control and a data line so that charge produced in the diode is read out in response to light emission from the scintillator

c.f, GE FFDM manual

Radiographics 2004:24,1753
# Technologies for FFDM – Indirect Capture

**GE**

<table>
<thead>
<tr>
<th></th>
<th>2000D</th>
<th>DS</th>
<th>Essential</th>
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<tbody>
<tr>
<td>Detector size</td>
<td>19.2 x 23.0</td>
<td>19.2 x 23.0</td>
<td>24.0 x 30.7</td>
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<td>Pixel size</td>
<td>100 µm</td>
<td>100 µm</td>
<td>100 µm</td>
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<td>Limiting Spatial</td>
<td>5 lp/mm</td>
<td>5 lp/mm</td>
<td>5 lp/mm</td>
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<tr>
<td>Resolution</td>
<td></td>
<td></td>
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<td>1914 x 2294 pixels (9 MB)</td>
<td>1914 x 2294 pixels (9 MB)</td>
<td>2394 x 3062 pixels (14 MB)</td>
</tr>
<tr>
<td>Bit Depth</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>
Technologies for FFDM – Indirect Capture

GE –

- **Advantages and Disadvantages**
  - Bonding between CsI and a-Si ensures minimal light loss
  - Strong signal from the Si diode array yields higher detective quantum efficiency
  - Detector is linear over a wide range ($10^5$)

- Limiting factor is the large pixel size (100 μm)
- Smaller pixel sizes improve spatial resolution but at the cost of increased image noise and decreased SNR for the same breast dose
- Possibility of ghosting in images
Technologies for FFDM – Indirect Capture
Fuji – CR technology

c.f: Bushberg, Third edition, pg. 266
Technologies for FFDM – Indirect Capture
Fuji – CR technology

- Fuji FCRm, Dual-side reader

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
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</thead>
<tbody>
<tr>
<td>Detector size</td>
<td>18 x 24</td>
</tr>
<tr>
<td></td>
<td>24 x 30</td>
</tr>
<tr>
<td>Pixel size</td>
<td>50 µm</td>
</tr>
<tr>
<td>Image size</td>
<td>3328 x 4096 pixels (24 MB)</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>10 lp/mm</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>14 bits</td>
</tr>
</tbody>
</table>

http://www.fujimed.com/
Technologies for FFDM – Indirect Capture
Fuji – CR technology

• **Advantages and Disadvantages**
  • Film-screen cassettes can be replaced by CR cassettes without replacing the entire system
  • Both small and large cassettes can be accommodated by the reader
  • Dual side reader, 50 μm pixel size

• Effective pixel size influenced by phosphor thickness, light diffusion within phosphor, laser light scatter & diameter of laser beam
• Technologist time on processing of images
• Noise associated with the low collection efficiency of emitted light
Technologies for FFDM – Indirect Capture
Fischer – SenoScan (not available now)

- A narrow slot-detector and a narrow fan beam of x-rays are scanned synchronously across the full field of view to cover the entire breast
- System consists of phosphor (thallium-activated CsI) with fiberoptic coupling to a CCD
## Technologies for FFDM – Indirect Capture

**Fischer – SenoScan (not available now)**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Fischer SenoScan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector material and design</td>
<td>Caesium iodide with 4 CCDs</td>
</tr>
<tr>
<td>Detector area (cm)</td>
<td>21 x 1 *</td>
</tr>
<tr>
<td>Maximum field size (cm)</td>
<td>21 x 29</td>
</tr>
<tr>
<td>Image acquisition time (s)</td>
<td>12 to 15</td>
</tr>
<tr>
<td>Image matrix (pixels)</td>
<td>4096 x 5625</td>
</tr>
<tr>
<td>Pixel pitch (µm)</td>
<td>25 or 50</td>
</tr>
<tr>
<td>High contrast limiting resolution</td>
<td>13 (at 25 µm)</td>
</tr>
<tr>
<td></td>
<td>10 (at 50 µm)</td>
</tr>
</tbody>
</table>
Technologies for FFDM – Indirect Capture
Fischer – SenoScan (not available now)

- **Advantages and Disadvantages**
  - Compact detector that is less expensive compared to others
  - Excellent scatter rejection due to small volume of breast exposed at any time
  - No grid needed therefore less dose
  - Longer compression since scan times are longer (approx. 6 sec)
  - Powerful tubes, elaborate signal readout and image reconstruction required
### Comparison – Indirect Capture

<table>
<thead>
<tr>
<th></th>
<th>GE DS</th>
<th>Fischer Seno</th>
<th>Fuji FCRm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Detector size</strong></td>
<td>19.2 x 23.0</td>
<td>21 x 1</td>
<td>18 x 24, 24 x 30</td>
</tr>
<tr>
<td><strong>Pixel size</strong></td>
<td>100 µm</td>
<td>25 or 50 µm</td>
<td>50 µm</td>
</tr>
<tr>
<td><strong>Limiting Spatial Resolution</strong></td>
<td>5 lp/mm</td>
<td>13 lp/cm at 25, 10 lp/cm at 50</td>
<td>10 lp/mm</td>
</tr>
<tr>
<td><strong>Image matrix</strong></td>
<td>1914 x 2294 pixels</td>
<td>4096 x 5625</td>
<td>3328 x 4096</td>
</tr>
</tbody>
</table>
Technologies for FFDM – Direct Capture
Hologic – Selenia

- a-Se, photoconductor is deposited directly onto the a-Si TFT substrate enabling direct capture
- The a-Se detector directly converts x-rays to electron-hole pairs
- The a-Si TFT converts the electron-hole pairs to electronic signal

http://www.hologic.com/wh/digisel.htm
<table>
<thead>
<tr>
<th>Technologies for FFDM – Direct Capture Hologic – Selenia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector size</td>
</tr>
<tr>
<td><strong>Pixel size</strong></td>
</tr>
<tr>
<td><strong>Image size</strong></td>
</tr>
<tr>
<td><strong>Spatial Resolution</strong></td>
</tr>
<tr>
<td><strong>Dynamic Range</strong></td>
</tr>
</tbody>
</table>
Advantages and Disadvantages

Advantage is that the detector response function maintains its sharpness even with increasing thickness.

Potential weaknesses are the need for high biasing voltage, drifting of the dark signal and cost of detector.

Inherent sharpness of detector may also increase the severity of aliasing artifacts associated with undersampling on any digital detector.
Technologies for FFDM – Direct Capture

Fuji – Aspire HD

- Smallest pixel pitch of 50µm, a first in a dual-layer amorphous-selenium
- Direct Optical Switching Technology replaces the need to use TFT as in conventional DR FFDM
- Tungsten x-ray tube with a rhodium filter

Technologies for FFDM – Direct Capture
Fuji – Aspire HD

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector size</td>
<td>24.0 x 30.0</td>
</tr>
<tr>
<td>Pixel size</td>
<td>50 µm</td>
</tr>
<tr>
<td>Image size</td>
<td>3328 x 4096 pixels (24 MB)</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>&gt; 7 lp/mm</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>14 bits</td>
</tr>
</tbody>
</table>

Technologies for FFDM – Direct Capture
Siemens – Mammomat Novation

- a-Se, photoconductor with TFT array

<table>
<thead>
<tr>
<th>Detector size</th>
<th>24.0 x 29.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pixel size</strong></td>
<td>70 µm</td>
</tr>
<tr>
<td><strong>Image size</strong></td>
<td>3328 x 4096 pixels (24 MB)</td>
</tr>
<tr>
<td><strong>Spatial Resolution</strong></td>
<td>&gt; 7 lp/mm</td>
</tr>
<tr>
<td><strong>Dynamic Range</strong></td>
<td>14 bits</td>
</tr>
</tbody>
</table>

http://www.medical.siemens.com
## Comparison – Direct Capture

<table>
<thead>
<tr>
<th></th>
<th>Hologic Selenia</th>
<th>Siemens Novation</th>
<th>Fuji Aspire HD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Detector size</strong></td>
<td>24 x 29</td>
<td>24 x 29</td>
<td>24 x 30</td>
</tr>
<tr>
<td><strong>Pixel size</strong></td>
<td>70 µm</td>
<td>70 µm</td>
<td>50 µm</td>
</tr>
<tr>
<td><strong>Limiting Spatial Resolution</strong></td>
<td>&gt; 7 lp/mm</td>
<td>&gt; 7 lp/mm</td>
<td>10 lp/mm ?</td>
</tr>
<tr>
<td><strong>Image matrix</strong></td>
<td>3328 x 4096</td>
<td>3328 x 4096</td>
<td>3328 x 4096</td>
</tr>
<tr>
<td></td>
<td>2560 x 3328</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Planmed

- 85 μm pixel size
- Amorphous selenium (a-Se) direct-conversion detector
- Two detector sizes - 17x24 cm (Planmed Nuance) and 24x30 cm (Planmed Nuance Excel)
- Tungsten tube, Ag/Rh filters

http://www.planmed.com
Giotto

- 85 μm pixel size
- Amorphous selenium (a-Se) direct-conversion detector
- Two detector sizes - 18x24 cm and 24x30 cm
- Tungsten tube, Rh filter

http://www.imsitaly.com/downloads.html
Technologies for FFDM

The Evolution of Digital Detectors

Direct

- a-Se/
- optical
- switching

Mammo

- Fuji/Kodak/
- Agfa/Philips
- Fischer (Hologic)
- GE
- Planmed
- Giotto

DirectRay® Detector

Amorphous Selenium

Field electrode

Dielectric layer

Semi-conductor
(α-Selenium)

Electrode collection array
with a-Silicon Thin-Film Transistor (TFT)

matrix and storage capacitor

Hologic

Siemens

Fuji Aspire
HD

Photon Counting Technology

- Slides are Courtesy of Dr. Eric Berns and Philips
Digital Mammography Technology Overview

**Digital Mammography**

- **Direct conversion**
  - Analog-to-Digital
  - True Digital
    - a-Selenium
    - Photon counting
    - Crystalline silicon

- **Indirect conversion**
  - Analog-to-Digital
  - Delayed processing
    - CR – storage phosphor
  - Non-delayed processing
    - a-silicon
Photon Counting Technology

- Direct multi-slit scanning
- Crystalline silicon detector

![Diagram of X-ray photon, photon counting detector, digital signal, and binary number]

5 (00000000000101)
Electronic Noise Removal

![Diagram showing Energy, Photons, Threshold 1, Noise, and a mammogram image.]
Multi-slit detector module scans the breast.

No anti-scatter grid required.

Module contains 50 um detector elements, 21 detector lines.
Photon Counting in Practice

MicroDose

X-ray tube
Collimator 1
Object
Collimator 2
Detector
Moving parts
Scan Motion
DQE – A Measure of Dose Efficiency

Dose Efficiency

Modulation Transfer Function (MTF)

- MTF is a measure of signal transfer over a range of frequencies and quantifies spatial resolution.

Yaffe - Radiology 2005:234,353

Modulation Transfer Function (MTF)

- Bloomquist et al - DMIST trial
Detective Quantum Efficiency (DQE)

- Detective Quantum Efficiency (DQE) measures SNR transfer through the system as a function of spatial frequency and is a good measure of dose efficiency.

**FFDM – Radiation Dose**

- Bloomquist et al - DMIST trial

<table>
<thead>
<tr>
<th>System</th>
<th>N</th>
<th>(\mu\text{C/kg})</th>
<th>mR</th>
<th>Range mR</th>
<th>MGD mGy</th>
<th>Range mGy</th>
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<tbody>
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<td>Fischer</td>
<td>26</td>
<td>144</td>
<td>560</td>
<td>400–750</td>
<td>1.31</td>
<td>0.81–1.79</td>
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<td>Fuji</td>
<td>25</td>
<td>278</td>
<td>1080</td>
<td>270–1660</td>
<td>1.87</td>
<td>0.79–2.69</td>
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<td>GE</td>
<td>46</td>
<td>196</td>
<td>760</td>
<td>410–1410</td>
<td>1.49</td>
<td>0.84–2.53</td>
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<tr>
<td>Lorad DBI</td>
<td>11</td>
<td>294</td>
<td>1140</td>
<td>540–1610</td>
<td>1.98</td>
<td>1.10–2.70</td>
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<tr>
<td>Lorad Selenia</td>
<td>13</td>
<td>273</td>
<td>1060</td>
<td>620–1830</td>
<td>1.85</td>
<td>1.09–2.98</td>
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<tr>
<td>All</td>
<td>121</td>
<td>219</td>
<td>850</td>
<td>270–1830</td>
<td>1.62</td>
<td>0.79–2.98</td>
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<tr>
<td>Screen-film</td>
<td>149</td>
<td>304</td>
<td>1178</td>
<td>708–1810</td>
<td>1.90</td>
<td>1.24–2.72</td>
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</table>

Bloomquist – Medical Physics 2006:33 (3), 719
**Storage of Digital Images**

<table>
<thead>
<tr>
<th>DETECTOR TYPE</th>
<th>FOV (cm)</th>
<th>PIXEL SIZE (mm)</th>
<th>IMAGE SIZE (MB)</th>
<th>EXAM SIZE (MB)</th>
<th>+3 Y PRIORS (MB)</th>
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<tbody>
<tr>
<td>Indirect TFT</td>
<td>19 × 23</td>
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<td>35</td>
<td>140</td>
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<td>15</td>
<td>60</td>
<td>240</td>
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<tr>
<td>Direct TFT</td>
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<td>0.07</td>
<td>18</td>
<td>70</td>
<td>280</td>
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<tr>
<td>Direct TFT</td>
<td>24 × 29</td>
<td>0.07</td>
<td>27</td>
<td>108</td>
<td>432</td>
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<td>CR</td>
<td>18 × 24</td>
<td>0.05</td>
<td>32</td>
<td>128</td>
<td>512</td>
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<td>CR</td>
<td>24 × 30</td>
<td>0.05</td>
<td>50</td>
<td>200</td>
<td>800</td>
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</tbody>
</table>

c.f: Bushberg, Third edition, pg. 267
Display of Digital Images

Radiographics 2004:24,1757
Economics of FFDM

- SFM systems cost well under $100,000
- FFDM systems cost in the range of $300,000 - $450,000
## FFDM Reimbursement

<table>
<thead>
<tr>
<th>CPT/HCPCS Code</th>
<th>Description</th>
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<tr>
<td>60202</td>
<td>Screening mammography, digital</td>
<td>$140</td>
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<td>Technical (TC)</td>
<td>$105</td>
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<tr>
<td></td>
<td>Professional (26)</td>
<td>$35</td>
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<tr>
<td>77057</td>
<td>Screening mammography, film</td>
<td>$81</td>
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<td>Technical (TC)</td>
<td>$46</td>
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<td></td>
<td>Professional (26)</td>
<td>$35</td>
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<tr>
<td>77052</td>
<td>Computer-aided detection (CAD), screening</td>
<td>$12</td>
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<tr>
<td></td>
<td>With film or digital mammography</td>
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<tr>
<td></td>
<td>Technical (TC)</td>
<td>$8</td>
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<td></td>
<td>Professional (26)</td>
<td>$3</td>
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<tr>
<td>60206</td>
<td>Diagnostic mammography, digital (unilateral)</td>
<td>$133</td>
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<td></td>
<td>Technical (TC)</td>
<td>$98</td>
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<td>$35</td>
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<td>60204</td>
<td>Diagnostic mammography, digital (bilateral)</td>
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<td>77055</td>
<td>Diagnostic mammography, film (unilateral)</td>
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<tr>
<td>77051</td>
<td>Computer-aided detection (CAD), diagnostic</td>
<td>$12</td>
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<tr>
<td></td>
<td>With film or digital mammography</td>
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</tr>
<tr>
<td></td>
<td>Technical (TC)</td>
<td>$8</td>
</tr>
<tr>
<td></td>
<td>Professional (TC)</td>
<td>$3</td>
</tr>
</tbody>
</table>
Expected Benefits of FFDM

- The costs of FFDM systems should be compared along with the inherent benefits of the digital technology prior to the purchase:
  - Reduced recall rates
  - Increased patient throughput
  - Increased early detection of breast cancer
  - Decreased false-negative biopsy results
  - Decreasing film and processing costs
  - Increasing the caseload of each mammography room
Clinical Trials and Phantom Studies

- Larger screening study screened 49,500 women
- *Digital Mammographic Imaging Screening Trial* (DMIST), funded by NCI and conducted by ACRIN (http://www.acrin.org/6652_protocol.html)

**CONCLUSIONS**

The overall diagnostic accuracy of digital and film mammography as a means of screening for breast cancer is similar, but digital mammography is more accurate in women under the age of 50 years, women with radiographically dense breasts, and premenopausal or perimenopausal women. (ClinicalTrials.gov number, NCT00008346.)
Advantages and Disadvantages

• Advantages
  – Optimize post-processing of images
  – Permit computer-aided detection to improve the detection of lesions
  – Storage of images easier

• Disadvantages
  – Image display and system cost
  – Limiting spatial resolution is inferior to film, 5-13 lp/mm vs. 20 lp/mm
  – Superior contrast resolution
Siting Requirements

- Room dimensions and power requirements needed depend on vendor equipment
- Breast support provides adequate primary barrier for radiation
- Typically 2 sheets or 28 mm of gypsum wallboard (sheetrock) provide adequate secondary shielding
- Technologist protected by lead shield, 0.3 mm lead
- Wood doors attenuate less than gypsum wallboard, may need metal doors or solid-core wood doors
- “X-ray on” light typically required on the door (in outside room/hallway)
Example – One Vendor

<table>
<thead>
<tr>
<th>ROOM DIMENSIONS</th>
<th>LENGTH &amp; WIDTH</th>
<th>CEILING HEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINIMUM:</td>
<td>10’-0” x 12’-0” [3.5m x 3.7m]</td>
<td>8’-0” [2.4m]</td>
</tr>
</tbody>
</table>
Educational Objectives

- Understand the physics of digital detector technology
- Recognize that vendors use varying detector technology in FFDM systems
- Appreciate the advantages and disadvantages of digital mammography systems
- Radiation Dose in FFDM systems
- Economics of FFDM systems
TAKE HOME POINTS

- Different technologies exist for digital systems – indirect and direct
- Commercially available FFDM systems vary in technology
- Many advantages exist for FFDM in comparison to FSM
- Dose is lower with FFDM compared to SFM
Resources

• Digital Mammography: An overview – Dr. Mahesh (Radiographics 2004;24:1747-1760)
• Fundamentals of Digital Mammography Primer – Dr. Smith (Hologic Inc)
• Digital Mammography – Pisano and Yaffe (Radiology 2005; 234:353-262)
• Bloomquist and Yaffe – Med Phys 33 (3), 2006
• MHRA report 05037: Comparitive Specifications of Full Field Digital Mammography Systems
• http://www.fda.gov/Radiation-EmittingProducts/MammographyQualityStandardsActandProgram/FacilityCertificationandInspection/ucm114148.htm
THANK YOU