DIGITAL MAMMOGRAPHY AND CLINICAL APPLICATIONS

ADVANCED HEALTH EDUCATION CENTER

OBJECTIVES
- Digital Mammography Basics
- Digital Mammography Theory & Physics
- Positioning with digital equipment
- Digital Artifacts
- Quality Control - what do These QC numbers Mean?
- Pathology of the Breast in the Digital World

BREASTCANCER.ORG

In 2012, an estimated 230,480 new cases of invasive breast cancer were expected to be diagnosed in women in the U.S., along with 57,650 new cases of non-invasive (in situ) breast cancer.

About 2,140 new cases of invasive breast cancer were expected to be diagnosed in men in 2012. A man’s lifetime risk of breast cancer is about 1 in 1,000.

About 39,520 women in the U.S. were expected to die in 2012 from breast cancer, though death rates have been decreasing since 1990 — especially in women under 50. These decreases are thought to be the result of treatment advances, earlier detection through screening, and increased awareness.

For women in the U.S., breast cancer death rates are higher than those for any other cancer, besides lung cancer.

In 2012, there were more than 2.6 million breast cancer survivors in the US.

- White women are slightly more likely to develop breast cancer than African-American women. However, in women under 45, breast cancer is more common in African-American women than white women. Overall, African-American women are more likely to die of breast cancer. Asian, Hispanic, and Native-American women have a lower risk of developing and dying from breast cancer.
- The most significant risk factors for breast cancer are gender (being a woman) and age (growing older).

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Diagnostic Performance of Digital versus Film Mammography for Breast-Cancer Screening
DIGITAL MAMMOGRAPHY BETTER AT FINDING CANCER IN YOUNG WOMEN

A study of 42,760 women at 33 sites across the United States and Canada, including Johns Hopkins, found that digital mammography is better than standard X-ray mammography at locating cancer in young women and those with dense breasts. The study, one of the largest Friday, September 16, 2005 breast cancer screening studies ever performed, was conducted by the American College of Radiology, funded by the National Cancer Institute, and reported September 16, 2005 in a special online publication of the New England Journal of Medicine.

Digital mammography detected up to 28% more cancers than X-ray mammography in women 50 and younger, premenopausal and perimenopausal women, and women with dense breasts, according to the American College of Radiology Imaging Network (ACRIN) Digital Mammographic Imaging Screening Trial (DMIST). However, the ACRIN results showed no difference between digital and film (X-ray) mammography in detecting breast cancer for the general population of women.

National Cancer Institute sponsored trial

IF YOU USE THE MAMMO PADS MOST OF THE TIME, YOU MUST USE THEM IN QC TESTING FOR PHANTOM......

WHAT WAS THE RUMOR ABOUT FULL FIELD DIGITAL MAMMOGRAPHY

○ The amount of compression that is to be given on a Digital Mammogram

COMPRESSION

○ Reduce breast thickness, which reduces geometric blurring
○ Reduce motion, unsharpness
○ Reduce scatter radiation
○ Increases contrast
○ Separates superimposed breast tissue
○ Reduces radiation dosage

BASIS FOR DIGITAL MAMMOGRAPHY

○ Lower Dose
○ Improved Image Quality
○ Computer-aided diagnosis software
○ Softcopy review and digital archiving
○ Elimination of physical storage
○ Large Dynamic Range (Range of exp.)
○ Increased exposure latitude
Before any new modality is used at a facility or before it is surveyed, all mammography personnel who will be associated with the FFDM unit must have 8 hours of documented training in that modality. That may be why you are here today!!!

At this time, full-field digital mammography units are required to submit images in hard copy format.

*Indirect capture – first converts the x-rays into visible light with a scintillator. The visible light is then converted into an electrical signal

*Direct capture – the x-rays are not converted into light but directly into an electrical signal

*Amorphous silicon (a-si) uses a scintillator to convert x-rays into light which is then captured by the photodiodes

*What was the scintillator used in film/screen?

*Contrast resolution – the number of shades of gray that a detector can capture

*High contrast resolution – capable of capturing thousands of shades of gray (far more than the human eye can appreciate) This permits the imaging of areas that would otherwise be under or overexposed on conventional film

Gd2O2S

Gadolinium oxysulfide
*CCD – charged coupled device – small computer chips which create a digital image used in fischer senoscan

*Micron – a unit of length equal to one millionth (1/1,000,000) of a meter

*Pixel – the basic unit of the composition of an image on a television screen, computer monitor, or a similar display (picture element)

*Scintillator – a substance that glows when hit by high-energy particles or photons

*Amorphous selenium (a-se) the Scintillator is replaced with the amorphous selenium plate that converts the x-ray photons directly onto electron-hole pairs

*DEL – detector element

*Dynamic Range – talking about latitude of the image that is recorded

*No more bucky, it is now called an image receptor or image detector.

*ellipse – symmetrical oval (elliptical)

*fiber optics – science of light transmission through very fine, flexible glass or plastic fibers

*SMPTE – a test pattern used for evaluating monitor calibration (Society of motion picture and television engineering

*Raid – redundant array of independent disks, provides image storage capabilities

*UPS – uninterruptible power supply that provides conditional line power to the review station computer, the raid and the magneto-optical drive. During a power failure the UPS automatically engages without losing data

*Magneto-optical drive (MO) – used to archive patient records for permanent long-term storage

*ADU – analog to digital unit

*RMS – root mean square

*Line pair – consists of two elements – a bar and a “space”. The bar is the high attenuating element and the space is the low attenuating element

*AWS – acquisition workstation - the monitor the images are initially acquired on during the procedure in the mammography room

*RWS – review workstation – the monitors the images are displayed on for the radiologist interpretation

*ROI – region of interest

*CR – computed radiology

**Algorithms**

○ Digital Mammography uses many different algorithms in the quality control program.

○ **Algorithm** is defined as a step by step problem solving procedure, especially an established, recursive computational procedure for solving a problem in a finite number of steps
**Tissue Equalization**
- The tissue equalization process happens automatically. Without equalization, window and level would be required to bring out detail.
- Tissue equalization allows visualization from the chest wall through the dense areas and to the skin line, without adjusting techniques and speed and without taking additional images.

**THICKNESS EQUALIZATION/COMPENSATION**
- A process where the detector looks at variations in pixel density across the image and estimates the thickness of the breast at each pixel.

**Histogram** - a chart representing a frequency distribution

**DQE** – detective quantum efficiency – an expression of the efficiency of an imaging system’s transfer from its input to its output of both signal and noise. It is expresses as a percentage. It is the measure most representative of image quality in terms of an observer’s ability to detect objects of interest in an image (Dose Efficiency). DQE is now the most important parameter in Digital mammography process.

Detector performance is commonly quantified by two metrics:
- Modulation Transfer Function (MTF)
- Detective Quantum Efficiency (DQE)

MTF is a measure of resolution.
DQE is a measure of dose efficiency.

Detective Quantum Efficiency (DQE)
Even with a high MTF at high spatial frequencies, small objects can get lost in the noise of the system. Increasing signal and decreasing noise (some electronic noise) in the system increases visibility of small structures.
MTF & DQE provide quantitative measurement of imaging performance.

MTF measures spatial resolution, while DQE is a measure of signal-to-noise ratio, contrast resolution and dose efficiency.
**Digital Mammography**

**Theory and Physics**

Advanced Health Education Center

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**Analog vs. Digital**

**Analog**
- Continuous in intensity values at a point variation of intensity from point-to-point

**Digital**
- Discrete in intensity values at a point locations at which values are known

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**Analog Verses Digital**

**Advantages**
- Time saved due to no film changing and no processing film
- Instant image to review
- Display with multiple optimizing capabilities
- Image storage minimal
- No lost films
- Constant updating of advanced applications

**Disadvantages**
- Initial cost very expensive
- Patient can see image asks many questions
- High maintenance cost due to computer knowledge needed from service personnel
- No lost films
- Constant updating of advanced applications

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**Analog Verses Digital**

**Advantages**
- everytime you print is the original image
- Fischer Senoscan Less dose due to collimation of beam therefore no grid needed.
- Pt does not need to hold breath on Fischer Senoscan because of the slot scanning speed
- Images never deteriorate

**Disadvantages**
- Computer systems detectors become obsolete
- New software upgrade cost
- Apprehension of new technology for radiologist/techs/pts
One of the biggest advantages of digital mammography is......

**DIAGNOSTIC PROCEDURES**

Per se, Pre-surgery needle localizations and Ductograms (galactograms), pneumocystograms. Sentinel lymph node needle guide. Less compression time. Less motion due to quick image recovery. Annotations on films for breast surgeons.

**Detector Types**

- Phosphor Curved CCD System
- Phosphor Silicon Flat Panel
- Selenium Flat Panel
- Computed Radiography System

**Charged Coupled Device (CCD)**

The CCD is a computer chip that is an analog to digital converter (ADC). The ADC accepts a continuously varying output signal (analog) and converts it to a discrete set of digital numbers.

- Fischer's slot scanning technology uses a tightly collimated x-ray beam that scans in precise alignment with a narrow slotted image receptor. The design essentially eliminates the negative effects of scatter radiation without requiring the use of a grid. The result is sharp, high-resolution images with up to 15% with Senoscan one and up to 60% with Senoscan 2 reduction in radiation dose, according to Fischer company.

**Phosphor CCD System**

- CsI(Tl) is deposited on a coupling plate consisting of millions of optical fibers.
- Fiber optics serve two roles, conduct light from the phosphor to a charge-coupled device (CCD) array, which converts light into an electronic signal that is digitized.
- The optical fibers stop much of the radiation that is not absorbed by the phosphor and thereby protect the CCD from the radiation damage that would result from direct exposure to x-rays.

**Detector Technology**

- Slot scanning detector (1 cm x 21 cm)
- 21 x 29 cm detector (imaging area size)
- A linear array of 4 CCD's optically coupled to a cesium iodide x-ray scintillator
- Standard resolution of 50 microns
- Diagnostic resolution of 25 microns
- Effective acquisition time 200 milliseconds (scan time @4-6 s)
COMPUTED RADIOGRAPHY (CR) SYSTEM

- This system employs a phosphor screen possessing a property called photostimulable luminescence as the x-ray absorber. Energy from x-ray absorption causes electrons in the phosphor crystal to be temporarily freed from the crystal matrix and then captured and stored in “traps” within the crystal lattice.

The image is then read out by placing the screen in a reader and scanning it with a red laser beam. This causes the electrons to be “knocked out” of the traps and to return to their original resting state. They will pass thru different energy levels.

The difference in these energy levels corresponds to the energy of blue light, which is given off by the phosphor when such transitions occur, thus the amount of blue light emitted and measured by an optical collecting system and a photomultiplier tube is proportional to the energy of x-rays absorbed by the phosphor. A filter in the optical chain prevents the stimulating red light from interfering with the measurement.

CR DETECTOR TECHNOLOGY

- 18x24 cm and 24x30 cm plate sizes
- 50 micron spot size
- 3540x4770 pixels (18x24)
- 4728 x 5928 pixels (24x30)
- Patient dose same as for film screen
- Image acquisition time same as for F/S
- Software available for CAD purchase

PHOSPHOR SILICON FLAT PANEL

- A scintillator layer such as cesium iodide is doped with thallium to capture the x-ray energy and convert the x-ray into light.

Then thin-film diodes convert the light photons into electronic signals that are captured using TFT’s.

Selenium Flat Panel

- X-rays are absorbed by a photoconductor and generates a signal. The photoconductor is amorphous selenium.
- Under the influence of an external electric field. Holes drift towards a pixel electrode and they are collected on a pixel capacitor.
- Little lateral charge spreading occurs.
- The photoconductor (Sel) is made sufficiently thick in order to stop the majority of incident X-rays.
- 95% of the X-rays are useful, compared to F/S that counts for 50/70 % of efficiency.

- Semiconductor arrays for direct conversion detectors are much easier to fabricate than arrays for indirect detectors because selenium-based detectors do not require a photodiode structure on top of the TFT.
In the direct acquisition detector, x-rays are absorbed by a thick photoconductor such as amorphous selenium (a-Se), which directly releases a corresponding number of electrons (and holes) that rapidly migrate under a large voltage placed across the selenium to the local storage capacitor.

**TUBES AND FILTERS**
- Ge- Mo/Rh anode Mo/Rh/Al filter
- Fischer-Tungsten/Rh target with aluminum filter is used due to the possible problem of excessive heat loading during the required duration of x-ray
- Lorad - Mo anode, Mo/Rh filter
- Siemens- Anode/ filter combo mo/mo, mo/rh/,W/Rh
  With a Tungsten Tube

**QUANTIZATION**
- **THE PROCESS OF MAPPING A CONTINUOUS VARIABLE TO A DISCRETE ONE**

**PIXEL SIZE**
- Spatial resolution depends on pixel size and the conversion method of the detector.
- Even with pixel sizes below 100 microns the spatial resolution of indirect capture detectors is limited primarily by light blurring in the scintillator.
- Direct capture systems do not have such limitations.

**THE MATRIX**
- The matrix is an area comprised of the number of pixels in the x and y coordinates (height and width)
  - The depth is measured in bits and is known as the different shades of gray.
  - 6 bit image = 64 shades of gray
  - 7 bit image = 128 shades of gray
  - 8 bit image = 256 shades of gray and so on
**THE MATRIX**
- An easy way to remember what a matrix is by thinking it like a straw.
- One straw = one pixel
- Length of straw = # of bits
- Longer the straw than the more information that can be stored
- Diameter of straw = resolution

**How many bits are there?**
- \(2 \times \text{the bit depth number}\)
  - Fuji CR system is 10 (1024) bit depth
  - Fischer Senoscan is 12 (4096) bit dep.
  - GE Senograph’s are 14 (16384) bit dep.
  - Lorad Selenia is 14 (16384) bit depth
  - Siemens Novation is 14 (16384) bit depth

**Computer-aided detection (CAD)**
- Technology can significantly increase the number of cancers detected with mammography.
- CAD technology can help detect cancers in very early stages, when breast cancer treatment is most likely to be successful.

**Computerized Inspection of Mammograms - The Software**
- Currently, mammograms are visually examined by humans in search of subtle and complicated indicators of breast cancer. This can be a difficult, tedious, and time-consuming task since mammograms are complicated images and since only one in a thousand may show an abnormality of concern.

**Since the computer serves as a second opinion rather than acting alone, it doesn’t have to be perfect to make a substantial difference. Radiologists will continue to make the final diagnostic decisions.**
FDA approved systems:
- R2 ImageChecker® System
- CADX Medical Systems-Second Look™
- iCAD MammoReader™
- iCAD MammoReader II™
- iCAD MammoWriter™
- Kodak CAD system

CAD can mark up to about 20 Area's but only picks about 4 or 5. If two many marks were on the Image it would cover up most of Breast imaging and distract the Radiologist when reading.

• Each digital unit has its own way and different type of image storage
  *RAID (redundant array of independent disks) provides image storage capability for the senoscan. The standard 22 gigabyte raid has a storage capacity of approximately 3000 senoscan images. Multiple RAID arrays or arrays of higher capacity may be used with some system configuration.
  *MO (magneto-optical drive) The optional magneto-optical drive may be used to archive patient records for permanent long-term storage. Data stored on optical disk will not degrade overtime and is unaffected by electromagnetic influence.

• TO RESTORE EXAM IMAGES THAT have been previously, Restore function allows the operator archived to DICOM compatible PACS over a tcp/ip network or to the locally configured MO DRIVE

Digital Imaging and Communications in Medicine (DICOM) is a standard for handling, storing, printing, and transmitting information in medical imaging. It includes a file format definition and network communications protocol. The communication protocol uses TCP/IP to communicates between systems. DICOM files can be exchanged between two entities that are capable of receiving image and patient data in DICOM format.

DICOM enables the integration of scanners, servers, workstations, printers, and network hardware from multiple manufacturers into a PACS system. Devices come with DICOM conformance statements that identify which DICOM classes they support. DICOM has been widely adopted by hospitals and is making inroads in smaller applications such as dentist and doctor offices.
STORAGE

- Long Term – More than 1 month
  - Where images are kept for the life time of the patient
- Short Term – Local storage/Review Station
  - time depends on size of hard drive and size of studies - 2 weeks to 1 month
  - Need to pre-fetch prior studies from long term storage to short term storage for comparison

VOCAB FOR STORAGE

- PACS (picture archiving and communication system is generally required to make a digital mammography system economically viable
- CAD (computer-aided detection) computer-aided detection is defined as a diagnosis made by a radiologist who considers the output of a computer analysis of the image when making his or her interpretation

VOCABULARY FOR STORAGE

- DICOM (digital imaging and communications in medicine) has a standard that allows the connection of image acquisition units, displays, archives and reporting systems from different vendors, the practical integration of these devices usually hinges on a balance of technical and business factors.
- TCP/IP (Transmission control protocol/internet protocol) the suite of communications protocols used to connect hosts on the internet. It is built into the unix operating system and is used by the internet.

LASER PRINTERS

- The laser imager (printer) allows high-quality hard-copy images to be printed from the review station computer. Quality of the hard-copy images is similar to that of the on-screen image provided by the high-resolution monitor.

FDA POLICY AS OF 2012

- Question 5: We have an FFDM unit and do not keep hardcopy of our exams (we retain the images electronically). When patients request the release of their exam, we create a hardcopy for them. May we charge the patient for the cost of creating the hardcopy?
  
  The facility may not charge for creating the first hardcopy version of the mammogram. However, if the patient requests a second one or more additional hard copies copy of the mammogram, the facility may pass the costs of that reproduction the additional hardcopies on to the patient.
**TELEMAMMOGRAPHY**

- Time is wasted by the need to have both individuals and images in the same location in order to carry out a consultation, second opinion, and staging purposes for therapy treatment.
- Telemammography is one solution to the above problem. A telemammography system consists of one or more digital mammography units, linked by a network or communications line to one or more remote display workstations.
- For telemammography to be practical and cost effective, it is necessary to be able to do softcopy image interpretation.
- In the future, telemammography could allow consultation on difficult cases with experts anywhere in the world.

**TELEMAMMOGRAPHY**

- Some barriers for telemammography
  - Size of the digitized image (20-40Mbytes)
  - Combination of cost of transmission media verses time to transmit like high bandwidth compared to low bandwidth
  - Maintaining diagnostic quality for telemammography equal to current film base screening method

**SOMETHING TO REMEMBER..........**

- Although a facility may routinely use softcopy for diagnosis, a facility must be able to produce diagnostic quality hardcopy prints for patients and referring physicians and surgeons. At this time, the laser imager is the only device qualified for this task.

**TELEMAMMOGRAPHY**

- Uses satellite communications
- Usually located in large medical facilities
- Good for rural low populated areas

**TELEMAMMOGRAPHY**

- Other factors affecting telemammography are
  - File size for data archiving
  - Networking system software
  - Signal propagation times for satellite
  - Pacs
  - Medical community acceptance
**FDA Policy**

- Question 5: Can a facility copy or digitize a film screen mammogram and use that copied or digitized image for retention purposes or final interpretation?
  - No. While not allowed for final interpretation, copied or digitized images of previously obtained mammograms may be used for comparison purposes if the interpreting physician deems that acceptable. However, such images cannot be used toward initial or continuing experience requirements.
  - We recommend that if copied or digitized images are used for comparison purposes that only copiers or digitizers approved or cleared by FDA’s Office of Device Evaluation for such purposes be used. In addition, we recommend that phantom and clinical images produced by such copying or digitization pass all applicable quality control tests and be of such quality that if they were submitted, they would pass the facility’s accreditation body’s phantom and clinical image review process.

**Positioning & Clinical Applications**

**Advanced Health Education Center**

**Fast Paddle**
- Fast (Fully, Automatic, Self-Adjusting, Tilt)
- It is spring loaded and tilts

**S.O.F.T Paddle**
- SOFT (Special, Optimized, Full, Tilt)
- Fixed tilt, always angled down same degree
breast implant interference with imaging breast tissue, with between 22% and 83% of mammographically visualizable breast tissue obscured by breast implants special techniques needed to maximize breast tissue visualization for women with breast implants a delay in breast cancer detection in women with implants, but without increased mortality to women with implants.