Image Acquisition, Display and Informatics

Dawn Derenburger, R.T.(R)(M)(ARRT)
Consultant – Mammography Educators
www.mammographyeducators.com

Special thanks to Fabiola Perez, RTRM for her contributions to this presentation.

Objectives

- Review the process by which digital mammogram images are acquired
- Discuss the advantages and disadvantages of digital mammography
- Learn digital mammography terminology and definitions

Digital Mammography

- Digital mammography uses traditional x-ray generators and tubes to produce an x-ray beam. This x-ray beam is converted into digital information which can be stored electronically, transmitted, displayed, analyzed and manipulated in a number of ways.

Digital Mammography

- Analog – molybdenum/rhodium targets and filters
- Digital – tungsten targets
  - –0.05 mm rhodium filter for fatty
  - –0.05 mm silver filter for dense
  - –0.7mm aluminum minimum (Hologic Tomo)

Advantages of Digital Mammography

- Better penetration of dense tissue
- Allows the use of the picture archiving and communication systems (PACS)
- Use of teleradiology
- Images can be viewed on multiple monitors or transmitted outside of the facility

Advantages of Digital Mammography

- Images from multiple modalities can be viewed from any monitor within the facility
- Efficient system that reduces the time it takes to complete an exam
- May reduce number of images that were repeated due to improper exposure

Possible Disadvantages

- Initial cost
- Possibility of failures in backup systems and loss of digital images
- Elimination of an on-site radiologist
- Technologist awareness of manual technical factors and patient radiation safety

Computed Mammography Systems (CM)

- Detector Technology
  - PSP – photostimulable phosphor or computed mammography
  - Uses image plate vs. cassette
  - Mammography unit with IP and computer reader

Computed Mammography Systems (CM)

- Image plate or cassette
- Processing reader
- Computer
- Display monitor

CM Systems

- Image Plate
  - cassette with a radiolucent cover, allows x-rays to enter and expose the photostimulable phosphor material

PSP Layers

- Protective Layer – protects from damage
- Phosphor Layer – activates and stores
- Conductive Layer – captures and holds electrons
- Support Layer – base for other layers

PSP Layers

- Light shield Layer – prevents light from erasing information
- Backing Layer – protection for the back of the image plate

Process of the CM System

- X-rays strike the PSP to produce and store a latent image
- Computer reader opens the IP to remove the PSP
- Image is scanned, read and PSP is erased and returned to the IP.

Image Retrieval Process for CM

- PSP is scanned with a focused infrared beam
- Light that is released and transmitted to an analog-to-digital converter (ADC)
- Analog signal converts to binary language or number data (Digital signal)

Binary Language

- Language that computers understand
- Digital signals are numeric data
- Analog signals are electrons in the form of light (varying shades of gray)

Image Display Process of CM

- Digital signal is transferred to a computer to process
- Binary data is converted to analog signal to display at review monitor

Advantages of CM

- Faster than analog
- Improved workflow
- Reduces repeats that are from over or under exposure

Disadvantages of CM

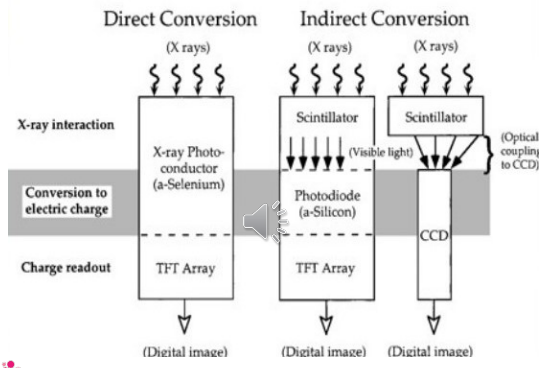
- IP and PSP's can be damaged
- Increased noise
- Decreased spatial resolution

Full Field Digital Mammography (FFDM)

- FFDM
  - cassette-less system
  - built-in flat panel detector uses direct or indirect technology

Types of Digital Imaging

- Direct digital
- Indirect digital
- Photon-counting Image Capture



Reference (Goell, 2013)

Scintillator

- "A **scintillator** is a material that exhibits scintillation, the property of luminescence, when excited by ionizing radiation."

Reference: Wikipedia

Flat-Panel Detector Systems

- Direct: Captures the image directly on the detector to create the digital image
  - Optimal detail and resolution of image
  - No loss of data during transition
- Non-Scintillator based

Non-Scintillator Based

- Direct, two step process
- X-ray beam strikes photoconductor
- X-ray is converted to electrons
- High voltage charge releases the electrons

Non-Scintillator Based

- Electrons travel on a TFT (thin film transistor) to the DEL (detector element)
- Signal is sent to an ADC and then computer analyzed
- Computer displays image on an LCD Monitor (liquid-crystal display)

Scintillator Based

- Indirect: Captures the image on an IR and then digitized through an image processor
  - Three step process
- Loses image detail
- Compromise between efficiency and resolution

Scintillator Based

- Beam strikes scintillator
- Cesium iodide converts x-ray to light
- Light strikes photoconductive material TFD (thin film diodes)

Scintillator Based

- Light converted to electrons
- Electrons move to DEL on TFT and sent to ADC and computer
- Computer displays image on LCD monitor

Thin Film Transistor

- Used to accept and store electrons to generate charge from the stored electrons
- Direct – uses amorphous selenium
- Indirect – uses amorphous silicon

Detector Element (DEL)

- Gathers the electrons to make up the components of the digital image
- Size controls the spatial resolution and contributes to image blur
- Set by the manufacturer

Fill Factor

- Ratio of the sensitive area (DEL's) to the entire detector.
- Spatial resolution
- Signal to noise (SNL) ratio

Direct Digital Detectors

- No intermediate step to convert x-rays to light
- A semiconductor (a-Selenium) **directly** converts x-rays to electrons
- Electrons read by TFT (thin-film transistor array)
- Produces a precise signal profile – no image blur

Advantages of Flat Panel Systems

- No plates or cassettes
- Increased detective quantum efficiency (DQE) better conversion for quality image

Disadvantages of Flat Panel Systems

- Image delay
  - more noticeable with indirect systems vs. direct systems due to conversion of energy

Photon Counting Image Capture

- Crystal silicon detector
- Photon counting electronics
- No ADC needed or grid needed
- Tungsten and Al added filters
- Reduces patient dose

Advantages of Photon-Counting System

- Lower radiation dose
- No ADC needed
- Temperature tolerant

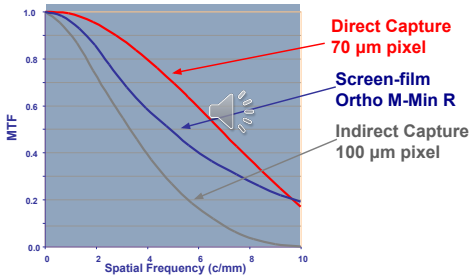
Disadvantages of Photon-Counting Systems

- Higher recall rates
- Challenges in positioning

Higher Modulation Transfer Function (MTF)

- A complicated mathematical formulation that basically represents the ratio of the image to the object.

MTF of Mammography Detectors



(Bunch, 1997 & Vedantham et. al., 2000)

Signal-to-Noise Ratio (SNR)

- All electronic systems have a constant amount of noise
- Signal produced must be greater than noise of detector

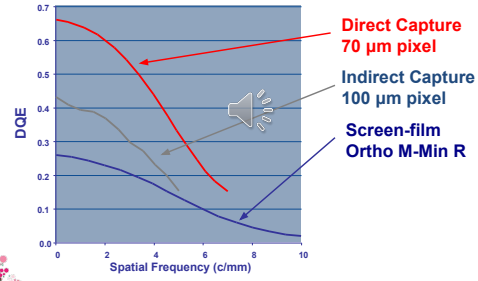
Signal-to-Noise Ratio (SNR)

- Detective Quantum Efficiency (DQE) is measure of signal-to-noise ratio transfer
- DQE also good measure of dose efficiency

Contrast-to-Noise Ratio (CNR)

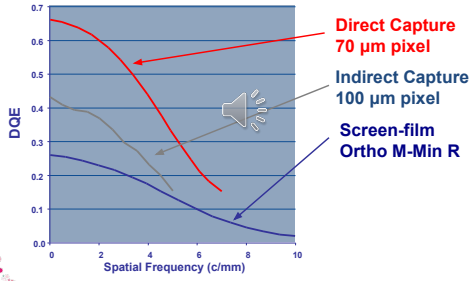
- Compares the image contrast to the background "noise"
- Ability to visualize microcalcifications
- Separates masses or other densities from the background density

DQE of Mammography Detectors



(Bunch, 1999)

DQE of Mammography Detectors



(Bunch, 1999)

Better DQE

- Better DQE means less noise in the image
- Less noise means better detection of low contrast pathology, e.g., masses
- Better detection means fewer missed cancers
- Lower noise means better visualization and higher confidence in diagnosis

ACR Phantom Score

(Effects of improved DQE and MTF)

Detector	Technology	Fibers visible	Specks visible	Masses visible
Kodak MinR 2000	Screen film	4	4	3
CCD	Indirect conversion	5.5	4	5
a Selenium	Direct conversion	6	5	5

Ref. Smith, A. (2003).

Monitors

- LCD used in Mammography
- Acquisition Work Station (AWS
  - For technologist use
  - Low resolution (2-3MP)
  - Ability to manipulate image after processed
  - Images sent from AWS to multiple outputs

Monitors

- Radiologists review workstations (RWS)
  - Must be approved for mammography interpretation
  - High resolution monitors (5MP)

Digital Image Storage and Transmission

- What happens to an image once it is accepted on the AWS?

DICOM

Wikipedia definition:

- Digital Imaging and Communications in Medicine (DICOM)
- Standard for handling, storing, printing, and transmitting information in medical imaging.

DICOM

- Includes a file format definition and a network communications protocol.
- Application protocol that uses TCP/IP to communicate between systems (Transmission Control Protocol/Internet Protocol)

Digital Image Storage and Transmission

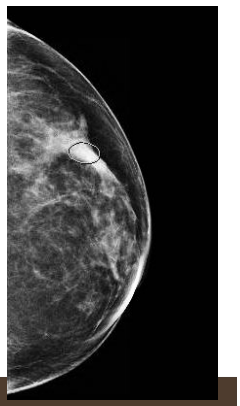
- What types of image files are we dealing with?
  - 2D
  - 3D
  - Tomosynthesis
    - Reconstructions
    - Synthesized view or C-View

Digital Image Storage and Transmission

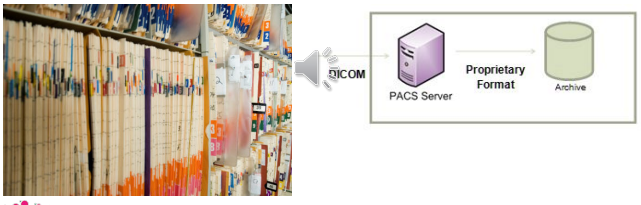
- What reconstructions, algorithms, or workflow systems are in place?
  - Software algorithms
    - CAD (Computer Aided Detection)
    - Volpara or Densitras (Image Quality)
    - Breast Density measurements

CAD: Computer Aided Detection

- Algorithm applied to raw digital images to help the Radiologist outline areas of possible concern.
- Software usually resides in a separate server offsite.

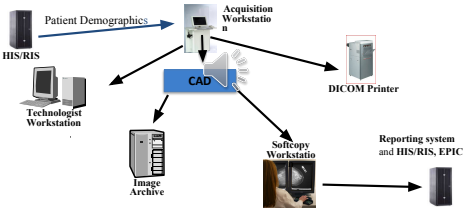


Digital Images = large data files



Digital Image Data Flow

Data is transmitted from acquisition station into PACS along with the other modalities.



Raw images vs. Processed images

- Raw Images
  - –Unprocessed, not for interpretation
  - –Contain all the DICOM raw data information to enable future reconstructions or processing algorithms

Processed Images

- Images processed for interpretation using the software algorithms and preset enhancements.

Storing or Archiving Images

- RIS – Radiology Information Systems
  - – networked software built for imaging systems.
- EMR – Electronic Medical Record
  - – used to manage patient records across the hospital network

Storing or Archiving Images

- HIS – Hospital Information System
  - – Software to include hospital and patient information

RIS, EMR and HIS are all capable of integrating with PACS for easy accessibility of images and patient records.

Digital Terminology

- LAN-local area network
- WAN-wide area network
- VNA-vendor neutral network
- Server
- Teleradiography
- PACS
- Lossy compression
- Lossless compression
- HL7

LAN vs WAN

- LAN – within the hospital
- WAN – larger overall area

VNA

Wikipedia Definition:

- A **Vendor Neutral Archive** (**VNA**)
- Medical Imaging technology in which images and documents are stored (archived)

VNA

- Standard format with a standard interface
- Can be accessed in a vendor-neutral manner by other systems

Server

Wikipedia definition: A server is a computer, a device or a program that is dedicated to managing network resources. Servers are often referred to as dedicated because they carry out hardly any other tasks apart from their server tasks.

Server

- It facilitates the hosting and delivery of high-end consumer business applications, which are used by multiple and simultaneously connected local or remote users

Teleradiography

- Transmission and viewing of images remotely
- Internet, phone, cable
- Uses DICOM interface

PACS

Picture Archival Communication System

- Short term image storage enabling interpretation of imaging exams
- Variety of vendors available such as:
  - AGFA
  - FUJI
  - Sectra
  - Merge

Lossy Compression

- Used in general radiography
- Compresses data file 100:1 or greater
- Teleradiography
- Does not compress CAD

Lossless Compression

- Compresses large data files by 10-50%
- Used in mammography
- Compresses and provides reconstruction of the exact original image

HL7

- Manages non-imaging data
- Interfaced with patients EMR (electronic medical record,) and EHR (electronic health record) for multiple purposes such as billing.
- IHE (Integrating the Healthcare Enterprise): Radiology DICOM information interfaces with HL7

Acquisition Workstation Outputs

- When an image is "accepted" or exam is "released" (depending on the manufacturer) images are sent to preconfigured destinations set by the service engineer and facility IT.

Acquisition Workstation Outputs

- Some possible outputs:
  - –Printer
  - –CAD
  - –CD
  - –PACS
  - –Reconstruction box
  - –Review workstation (manufacturer specific)

Outputs

- Processed and raw data sets can be sent out in combination or individually to desired destinations as determined by software or lead interpreting physician.

Outputs

- Some of the outputs may be combined for normal operation and QC purposes.
  - –CD/Flash drive and Printer for QC
  - –CAD Review workstation for display and PACS for long term storage

AWS Image Transmission Errors

- When the destination to which an image is sent is down or blocked, a message will display on the AWS monitor or display system.

AWS Image Transmission Errors

- When the messages or alarms display:
  - –Check the status browser or managed queue logs to determine which output is causing the problem.
  - –Once the root of the problem is identified, you can call the correct service center to reboot or fix that specific server, CPU or application.

System Components and Routing Information

When calling for service, it is always important to have the following information for each component of the system to facilitate expedition of services

- System ID/serial #
- AE title
- IP address
- MAC ID
- Port #

System Components and Routing Information

- This information is what identifies each component and are established at the time of installation. It is very important to keep this information handy and keep track of any changes.

Burning CDs or Printing images for transfer of care and 2nd opinions

- When a patient request copies of their digital images:
  - –Print diagnostic copies from laser printer (QC is required)
  - –Burn standard 2D images onto a CD

Burning CDs or Printing images for transfer of care and 2nd opinions

- –Tomo images can only burn 2D images and synthesized views (c-view, v-previews) due to extremely large data files. (Larger than MRI and CT!)

In Summary

Advances in technology continue to allow for improvements in the quality of breast imaging. Digital mammography has proven to have several advantages and now provides a platform for future advancements in technology, such as Contrast Enhanced Mammography, allowing for the continued efforts in the early detection of breast cancer.

Thank you!

For questions or more information, contact us at:

www.mammographyeducators.com

619-663-8269

info@mammographyeducators.com

Services we offer include:

- On-site Positioning Training
- Assistance with Accreditation & Inspection Processes
- Live Webinars
- Customized Continuing Education Programs

References

Bunch,PC (1999) GE Senographe FDA PMA.

Bunch, SPIE 3031 (1997) Vedantham et. al., Med. Phys. 23 (2000).

Goel M.D, M (2013) Computed Radiography & Digital Radiography https://www.slideshare.net/mohitgoel9212/cr-dr-50287860

Peart, O.J. (2018) Lange Q & A Mammography Examination 4th Edition.

Smith, A. (2003). Fundamentals of digital mammography: physics, technology and practical considerations.