

Breast Imaging Technologies Past, Current & Future

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Early Detection



- Visual detection
- Advanced breast cancer



Standard Treatment

- Cauterization
- Exorcism
- Topical pain relieving ointment
- Special diets



The Renaissance - 1542

- A period of great discovery
- Radical mastectomy as treatment option
- Cauterization to control bleeding
 - Pioneered by Flemish physician Andresa Vesalius (1514-1564)
- Human body dissected
 - New teaching style
 - Detailed anatomy



Significance of Lymph Nodes

- Breast cancer spread to the lymph nodes
 - French surgical writer Heri le Dran (1685-1770)
- Radical mastectomy become the preferred method of treatment



New Hope

- Introduction of nitrous oxide in 1867
- 1928 – discovery of penicillin
 - 1940s improved antiseptic conditions





Breast Cancer Stats -1960s

Before mammography

- Physical examination was the only method of detection
- Cancers were large on discovery
- Mastectomy on only advanced cancer cases
- 10 yr survival rate = 12% with a 30% local recurrence rate



Recommendation for Mammography



- 1963 -HIP of new York began the first mammography trial
- 1971 - HIP reports the mammography reduces breast cancer deaths by 31% in women over 50
- Carcinogenic effects of mammography outweighed by benefits



Dedicated Units

- Better imaging techniques
 - Improved contrast
 - Increased resolution
 - Increased sensitivity
- Decrease radiation dose to breast
 - Reduced radiation risk



Xeromammography



- Used tungsten target
- A dry process system
- Prints blue and white images
- Images viewed without a lightbox
- Larger latitude than screen-film
- High radiation dose

Disadvantages of Mammography

- Cancer is visualized as a white area within the background density of the breast
- Sensitivity will depend on breast density, patient age or hormone status
- Mammography tends to understate the multifocality of a lesion
- Inadequate compression and poor positioning will affect interpretation

Mammography



- Not 100% effective
- Effectiveness improved with
 - BSE
 - CBE
 - Adjunctive imaging modalities



Imaging Modalities

- Digital mammography
- CAD technology
- Ultrasound
- MRI
- Molecular imaging
 - PEM – FDG
 - Breast scintigraphy/
 - Lymposcintigraphy/sentinel node mapping
- Computed tomographic laser mammography
- Digital tomosynthesis and others



Analog Imaging

The Film
Capture the Image
Store or Archive
Display the Image

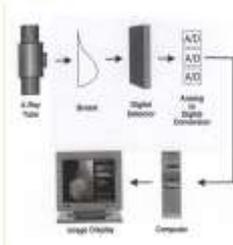


Disadvantage of Film

- Easily lost
- Storage cost
- No adjusting for under or over exposure



Digital Imaging



- Latent image – formed on digital detector
- Analog to digital converter
- Computer
- Display



Digital Mammography

There are two types of Digital Systems

- Digital Mammography
 - Cassetteless system
 - built-in detector technology
- Computer Mammography
 - Mammography Unit with IP plus Computer Reader (CR)
 - The IP is physically removed from the unit and inserted into the CR



Digital Imaging - CM



- The image is captured using a cassette based option



Computed Mammography Considerations



- Less expensive method of digital mammography
- A number of systems available
- Multi detectors
 - 18 x 24 cm
 - 24 x 30 cm



Digital Imaging - DM



- Image is captured on a built-in digital detector (no cassettes)



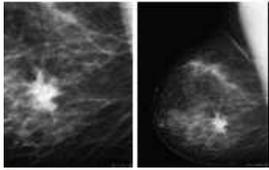
Digital Mammography Considerations



- Pectoral muscle on MLO
- Variable detector sizes
- Adjustment for small breast
- Various options available
 - GE
 - Hologic
 - Siemens
 - GIOTTO
 - Planmed Nuance
 - Sectra – Photon Counting



Biggest Advantage



- Wide latitude
- Linear response to the intensity of x-ray exposure
- Optimization of contrast



Digital Imaging



- Multiply display options:
 - Film, computer monitor or flat panel display
- Numerous storage or archival solutions:
 - Printed film, DLT, optical disk, RAID



Acquisition Work Station (AWS)



Soft Copy Display

- Rapid viewing of the image
- Post processing of image
- Modify patient demographic information
- Image resolution considerations

Radiologist - Display



- Flat panel display
 - High resolution display

Laser Printing



- Processing without chemicals
- No drainage needed
- No water connection
- Film can be handled under daylight conditions – no darkroom needed
 - Disadvantage
 - Very expensive
 - Optical density and latitudes lower

Input - Patient Information



- Work list
 - Patient's name selected from a list
- Magnetic card swipe
 - Patient's information on credit card-like device

Input - Patient Information

IP scanner

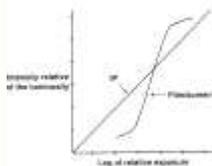


The Digital Image



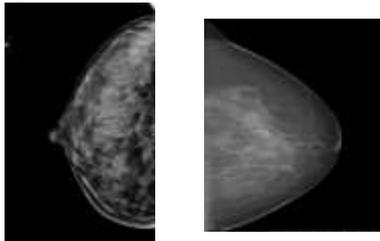
- Digital is formed as a 2-dimensional (2-D) matrix of pixels
- The greater the number of pixels per inch the greater the resolution
- Digital can correct exposure factors over 100% times greater than or 50% less than normal range

Characteristic Curves

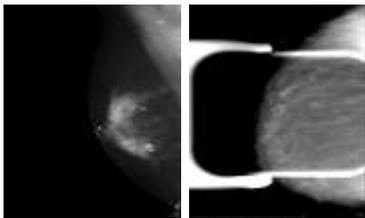


- Film contrast = slope of the straight line portion of the curve
- Latitude = range of exposures over which x-rays will respond to optical densities

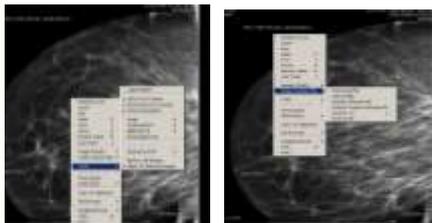
Dense and Fatty Breast



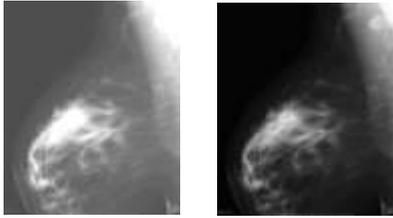
Calcification or Spot Compression



Post Processing



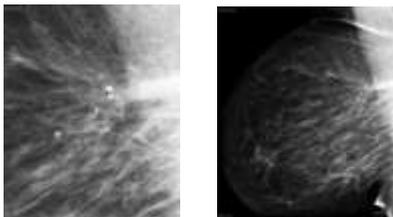
Change Brightness/Contrast



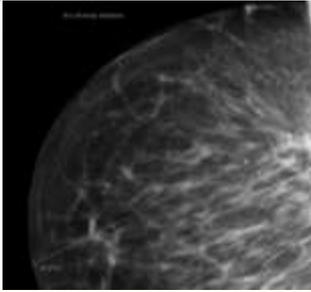
Inverting the Image



Digital Image Zoom



Add a Ruler or Text



Other Advantages of Digital



- Improve workflow by reducing repeats
- Reduce cost associated with repeats
- Reduction in lost films
- Every reprint is an original
- Medico legal risk reduced

Other Advantages



- Electronic image storage or archival in encoded form to reduce space
 - Short term -local storage on the hard drive
 - Medium term – redundant array of independent disks (RAID)
 - Long term -optical disk or digital linear tapes
- Compressed storage



PACS & Teleradiology

- PACS – complete Picture Archiving and Communication system
 - Modality comparison
 - Prior film comparison
- Teleradiology - images can be transmitted to distant locations e.g. Radiologist's home
 - Virtual consultation
- Internet access to images – via telephone, cable or satellite



Contrast Enhanced Mammography

- Utilizes the association of cancer with increase vascularity
 - Cancers need oxygen and food
- Iodinated contrast agents injected into an arm vein



Disadvantages of Digital

- Start-up cost
- Loss of experience with manipulating technical factors and film processing
- Loss of ability to control patient dose
- De-emphasize thinking of radiation safety and patient protection



Other Fears

- Outsourcing of reports – eliminating the need for a radiologist at any one site
- An insufficient backup system



Important Consideration



- Positioning in digital is just as important as in analog imaging
- Digital can legally be performed only at facilities that are certified
- Technologist needs documented training



Need for Computer Aided Detection

- 5-10% of potentially detectable breast cancers can be overlooked by radiologists on a screening mammogram
- Double reading will reduce the failure to perceive an abnormality but double reading is expensive



CAD – Computer Aided Detection



- Combining digital technology with computers to pre-read the mammograms
- The computer will display suspicious areas, in effect acting as a second reader



How It Works



- The breast is mapped for a normal reference
- The image is analyzed
- Microcalcifications and abnormalities are enhanced
- Normal structures are de-emphasized



CAD and Analog Imaging

- CAD technology works with both digital mammography and analog imaging
- A analog mammography image can be fed into the digitizer which sends the signals to the computer reader





Use of CAD



- Analog mammograms
- Digital mammograms
- Breast ultrasound
- Breast MRI



Sensitivity vs. Specificity

- High sensitivity will increase the false positive rate
- High specificity will reduce the number of false positives

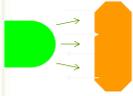


Sound & Ultrasound



- Sound is a mechanical longitudinal wave
- Measured units - hertz (Hz)
- Ultrasound uses high frequency sound waves

Principle of Ultrasound



- Based on piezoelectric effect
- Crystals vibrate and produce sound waves
- Sound sent through tissues bounce back
- Returning echo causes crystals to vibrate in proportional strength
- Computer analyzes the strength of returning echoes

The Transducer



- Converts electrical energy to acoustic pulses
- Receives the reflected echo and converts it to electrical signals
- Breast imaging uses
 - High frequency transducer (10MHz & above)
 - Linear array transducer

Ultrasound vs. X-ray

- Ultrasound uses:
 - No ionizing radiation
 - There are no documented risks or harmful bioeffects
- Sound cannot travel through a vacuum – a gel must be applied to the skin to act as a conductor



Use of Ultrasound

- Adjunctive imaging used in screening dense breast
- To determine if a mass seen on the mammogram is fluid-filled or solid
- To assess implants for leaks



Malignant Lesion



- Irregular shape/ ill-defined
- Angular /greater than 3 lobulations
- Microlobulated
- Spiculated margins
- Height greater than width
- Hypoechoogenicity
- Attenuating distal echoes
- Duct extension



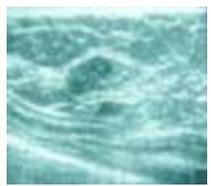
Benign Lesion



- Homogeneous hyperechogenicity
- Thin echogenic pseudocapsule
- Ellipsoid shape
- Fewer than 4 gentle lobulations
- Compressibility



Intermediate Lesion



- Echo texture
- Echogenicity similar to fat
- Normal or enhanced posterior echoes



Limitations of Ultrasound

- Only as good as the sonographer
- Sonographer must be able to differentiate between real and artificial echoes
- No nice landmarks
- Sound does not travel in a vacuum – gel needed
- Dedicated training needed to scan and interpret the images



Imaging Difficulties

- Cannot image microcalcifications
- Breathing and body size can affect imaging
- Normal folds or reverberations can suggest rupture on implant imaging
- The lactating breast can suggest pseudolesions



Doppler Effect

- The use of high frequency sound to image moving structure such as blood flowing in a vessel

Color Doppler

- Assigning different colors to blood flow
- Depending on their velocity and direction – (To vs. Away from the transducer)



3-D & 4-D Color Doppler

- An experimental technology use to display blood flow in the breast.
- Could be used to image highly vascular cancerous lesions.

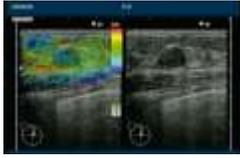


Volumetric Imaging



- SomoVu system
- Use of a single probe sweep using volume imaging protocol

Elastography



- Uses information from the ultrasound signal used to produce an image displaying the elastic properties of breast tissue
 - Differences in tissue stiffness
 - Cancers hard vs. Normal breast tissue)

Magnetic Resonance Imaging (MRI)



- No x-ray
- Complex magnetic properties
- Imaging performed with a paramagnetic compound – major element includes gadolinium

MR imaging of the breast approved by the FDA since 1991

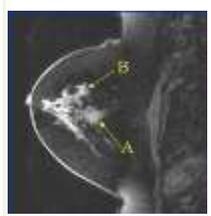
What Is MRI?



- The interaction of body tissue with radiowaves in a magnetic field
- Echoes or signals from the body are continuously measured by the MRI scanner
- A digital computer reconstructs the echoes into images of the breast



Why Contrast?



- Malignant lesions enhances and washes out rapidly
- Benign lesions enhances and washes out slowly



The Procedure



- The patient lies prone on the table with the breast falling into specialized breast coils
- The table slides into the bore
- Numerous points are sampled
- The examination can last 30-40 mins



Uses of Breast MRI



- Map tumor extent - as a staging tool to evaluate treatment options
- Locate retroareolar cancer
- Detect multifocal/multicentric diseases
- Detect recurrence
- Evaluate dense breast



Uses of Breast MRI



- To evaluate positive surgical margins for residual cancer
- To evaluate the effects of chemotherapy response
- To distinguish post-operative or post-radiation scarring from cancer
- To evaluate implants



Risks and Complications



- Metallic dangers
- Poorly visualizes the axillary nodes
- Cannot image calcification
- Expensive
- Time consuming
- Uses contrast – danger of NSF (nephrogenic systemic fibrosis)



Contraindications to MRI



- Cardiac pacemakers
- Aneurysms clips (intracranial)
- Intraocular ferrous foreign bodies
- Pregnant patients should consult their physician before imaging



Limits of Breast MRI

- High sensitivity but low specificity
- MRI will enhance fibroadenomas, and areas of inflammation





Magnetic Resonance Spectroscopy (MRS)

- Noninvasive imaging
- Measures the functional breast cancer byproduct – choline
- Uses high-field MR scanners
- Prevents unnecessary breast biopsies





Molecular Imaging

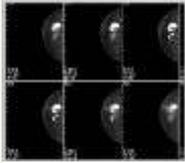
- Mammography findings are characterized by the difference in appearance between normal and suspicious breast tissue, BSGI findings are based on how cancerous cells function
 - Positron Emission Mammography (PEM)
 - MBI or BSGI - breast scintigraphy or scintimammography
 - Lymphoscintigraphy – sentinel node mapping

Positron Emission Mammography (PEM)



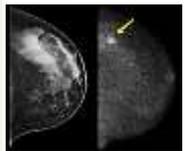
- Uses fluorodeoxyglucose (FDG) a radioactive tracer that is injected into the arm vein
- Special gamma scanners detect the radiation emitted

PEM Technology



- Cancerous tissue uses vast amounts of sugar
- Radioactive substance is metabolized in the body like sugar
- The tracer will go to the tissues that are most active

Use of FDG-PEM



- For patients with ambiguous mammogram
- To stage lymph node involvement
- Detect current and/or recurrent metastases
- Discriminating fibrotic scar, necrosis or tumor
- Staging and restaging
- Imaging augmented breast



Advances in PEM Imaging

- Combination or fusion technologies – combining PEM and CT/MRI
- Enables functional information of PEM to be fused with high-resolution anatomic images of CT
- Combine PEM and MRI complements the high sensitivity of breast MRI with PEM imaging



Precautions of FDG-PEM

- Patient must fast before the scan
- Patient must lie still for 60-90 minutes after the FDG injection
- No vigorous exercise allowed 48 hours prior to a PEM scan



Limits of FDG-PEM

- Tumor size and cell type affects PEM accuracy- cannot detect cancers smaller than 1cm
- PEM cannot replace sentinel node mapping
- Inflammation/infection /surgery distort PEM results



Breast-Specific Gamma Imaging (BSGI)/ Scintimammography/ MBI



- Injection of the drug technetium-99m(Tc99m) sestamibi
- Tracer accumulates in malignant lesions
- Mild compression of breast

Uses of Scintimammography



- Patients with indeterminate mammogram not referral for biopsy
- Patients with dense breast
- Breast cancer staging to show multifocal disease or axillary node involvement
- Extent of primary lesion
- Detect secondary lesions

Disadvantage of Scintimammography

- Does not detect lesions smaller than 1cm
- Some benign diseases give a false positive results
- Skin folds or muscles can mimic axillary uptake
- The radiopharmaceutical must be properly injected
- Uses 8-10 times radiation of mammogram



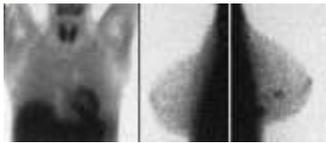
Lymphoscintigraphy

Sentinel node mapping

- The injection of a radiopharmaceutical into the subareolar lymphatic plexus (or lesion)
- The tracer travels to the sentinel node – identifying that node for dissection and eliminating the need for extensive lymph node dissection



Limitation of Lymphoscintigraphy



- Poor visualization of deep lymphatic system



Computerized Tomographic Laser Mammography - CTLM

- The breast is scanned 360-degrees for temperature differences indicating tumors
- Each breast scan takes 15-minutes
- The hemoglobin in a vascular tumor absorbs the CTML laser light
- CTLM approved for use in Canada, Europe and Asia,



Source: <http://www.ama-assn.org>



CTLM Procedure



- Patient lies on a table with breast suspended through a hole
- Low-wavelength laser scans the breast
- Bright green 3-D cross-section image of the breast obtained

Source: <http://www.inm...>



Advantages and Disadvantages

Advantages

- No compression or radiation
- Can image dense breast
- Can differentiate cystic vs. Solid lesion
- Can image implants

Disadvantages

- Cannot detect microcalcifications
- Difficult to image small breast



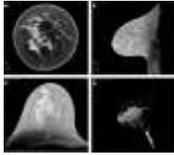
Optical Imaging

- Use of infrared light to penetrate breast tissue
- Extra blood vessels clustering a tumor distort light in a characteristic way
- Process will highlight the presence of tumors





Cone Beam Breast Computed Tomography - CBBCT



- The patient lies on a cushioned table with a cutout in the middle
- Breast are suspended through an opening
- The scanner takes 360-degree scans without compression – 300 images in 10 sec
- Can distinguish small lesions and can image calcifications
- Drawback:
 - Difficulty imaging details of calcifications



Digital Tomosynthesis



- No movement of the patient
- High resolution cross-section 3-dimensional images
- Eliminates overlapping structures
- The # of reconstruction images based on the breast thickness in mm.



Conclusion

- Mammography is still the most comprehensive tool in the fight against breast cancer
- Adjunctive modalities are available and should be utilized



Thank You!