IN THE BEGINNING

Mammography technology has come a long way since the first machine specifically designed for producing mammograms was introduced in 1966.

EARLY MILESTONES IN MAMMOGRAPHY

- 1913 - Albert Solomon, a surgeon in Berlin, uses a conventional X-ray machine to visualize breast cancers in 3,000 mastectomy specimens.
- 1949 - Uruguayan Raul Leborgne emphasizes the need for breast compression to identify calcifications.
- 1956 - Robert Egan, a radiologist in Houston, introduces dedicated film for mammography to produce simple and reproducible images with improved detail.
- 1966 – The first dedicated mammography system is introduced.
- 1971 – Commercial introduction of xeromammography.
- 1980 – Introduction of single emulsion film; 2x faster at significantly lower dose.
REMEMBER THIS?
1953 Uruguay
If you do, you’ve been working way too hard…and too long!

DEDICATED MAMMOGRAPHY SYSTEMS
- The first systems developed specifically for mammograms were released in 1966.
- Rotating C-arm allowed both CC and MLO views to be taken with patient in standing or sitting position, for better efficiency
- Additional diagnostic views enabled
- Image quality was limited due to limitations in film capabilities

EARLY POSITIONING AND COMPRESSION
- MLO view done in reclining position
- CC is standing position

MANY VENDORS SAW THE POTENTIAL...
- PHILIPS (LORAD)
- BENNETT
- CONTINENTAL
- LORAD TRANSPO
- CGR-500T
- GE800T
- INSTRUMENTARIUM
- GENRAD
- PLANMED
- SIEMENS

WHAT ABOUT THIS?
- Usually done when a patient had a very large palpable mass
- Limited productivity: 4-5 patients imaged per day
- Limited to CC and MLO views; no ability to do extra diagnostic views
If you remember this, I know your age!

FDA Approval
- Approvable Letter
- 510K—manufacturer “claims” product is substantially equivalent—used for proven technology—Today
- PMA—manufacturer “proves” product is substantially equivalent—used for new technology
OTHER BENEFITS
- More comfortable procedure for the patient
- Dedicated work areas for Radiologists and Technologists, for improved productivity
- Birth of the “team approach” in mammography

Is This Your Past

THE NEXT ADVANCE
XEROMAMMOGRAPHY
- First introduced in 1971
- Provided better image quality than systems using industrial film packs
- Allowed excellent visualization of chest wall
- The Grandpappy of Selenium digital technology
- Key Inventor – Lothar Jeromin (“Mr. Xerox”)
  - Holds 23 patents

XEROMAMMOGRAPHY DIFFERENT PERSPECTIVES
- LOVE
  - Radiologists and Surgeons loved the image quality and ability to see chest wall and ribs
- DREAD
  - Technologists were uncomfortable with length of exam and lack of training in positioning (all on the job, at that time)
- FEAR
  - Patients were very uneasy as the exam was not expected to bring good results (done primarily for symptomatic patients at that time)
AND IT APPEALED TO THE PUBLIC…

- Advertisement in Life and Glamour magazine promoting the new technology, xeromammography
- Your Mother’s Mammogram

AT THE SAME TIME…

- Single emulsion film for use in mammography was being introduced, with the promise of providing faster processing, improved image quality, and significantly decreased dose
- By 1986, screen-film mammography was being used by more than half of all radiologists
- Production of xeromammography was halted in 1989, due to declining sales
- Screen-film mammography became the gold standard in the late 1980’s – early 1990’s

BUT WHAT A MESS!

- Technologists were the original Smurfs!
- Lots of blue, on your shoes, uniforms, hands, hair etc.

A GLIMPSE OF THE FUTURE
LOTHAR’S STORY

- As a testimonial of faith in their xeromammography system, Xerox offered free mammograms to female employees in the breast cancer at-risk age group.
- ONE non-symptomatic woman was indeed diagnosed with breast cancer

And so the seeds of a screening program were sown ……

IMPROVEMENTS IN XEROMAMMOGRAPHY

- In 1985, xeromammography changed from blue powder toner to black liquid toner
- This resulted in substantial dose reductions (and cure of Smurf-syndrome in technologists)

80s AND 90s PROFICIENCY DEVELOPMENT

- Worldwide acceptance of mammography as the first line of defense
- Radiologists became MAMMOGRAPHERS and in many facilities multitasked
- Technologists began to seek out specialized training courses
- Administrators & Technologists worked together on creating “The Breast Center”
- MQSA enacted to ensure consistently high quality in all mammography facilities
MILESTONES IN MODERN MAMMOGRAPHY

- 1988 – Declaration of Breast Cancer Awareness Week, which led to Nation Breast Cancer Awareness Month
- 1988 – Congress passes legislation to provide annual screening mammography benefit for Medicare recipients
- 1990 – Breast and Cervical Cancer Mortality Prevention Act implemented to provide free or low cost mammograms and pap smears to low-income women
- 1998 – First Computer Aided Detection (CAD) system for mammography approved by FDA
- 1999 – National Mammography Quality Standards Act implemented
- 2000 – First Full Field Digital Mammography system approved by FDA

THE 80’S and 90’s DECADES OF AWARENESS

- Significant increase in incidence of breast cancer diagnoses between 1980 - 1987 attributed to implementation of screening programs, enabling earlier detection of smaller breast cancers
- Earlier detection has led to decreases in mortality
  - Breast cancer mortality rates have decreased approximately 2% annually since 1990!
- The “WAR” on Breast Cancer has been the biggest American accelerator for development of better detection technologies and improved treatment options in the last two decades

Breast Cancer Awareness has led to an intensified movement to promote life-saving early detection by

RADIOLOGISTS
TECHNOLOGISTS
PHYSICISTS
Typically, the previous 4 images are compared with the latest 4 images, 8 images viewed.

If radiologist interprets 40 patient studies/hour, = 1 study every 90 seconds.

Reviewing 8 images every 90 seconds = 11 seconds per image!

(In USA), screening Mammography exam is two views per breast, = 4 images/study.

FOUR DECADES LATER

The “Star Wars” fantasy of beaming digital mammograms via satellite to doctors in remote locations around the world has become a reality.

Breast Tomosynthesis

A 3D screening modality that preserves the very high resolution of 2D FFDM. Multiple images of the breast are acquired at different angles during a sweep of the x-ray tube. Allows radiologists to see around overlapping structures.

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Breast Tomosynthesis
In 2D FFDM:
- Tissue superimposition hides pathologies in 2D
- Tissue superimposition mimics pathologies in 2D

Tomosynthesis is a three-dimensional mammographic examination that can minimize the effects of structure overlap within the breast.

Tube moves in a 15° arc
- 15 low dose images are acquired
- 1 image at each degree
- Four second sweep
- Images are reconstructed into 1 mm slices

In combo-mode imaging, the 2D and 3D are taken in the same compression, with no additional positioning for the patient.
A 2D Mammography Image with a suspicious area identified and blown up.

The 2D Mammography Image next to one slice of a 3D Image Set.

Recall Reduction Superimposed Tissue Examples.

Hologic C View.
**C-View**
- 2D reconstruction algorithm
- Eliminates the need for a 2D mammogram
- Creates synthesized images from single tomosynthesis scan
- Reduces dose
- Additional cost

**GE SenoClaire**
- Routine for GE tomosynthesis-FDA Approval-Screening
  - 2D CC
  - 3D MLO
- Diagnostic Exam
  - 3D CC
  - 3D MLO

**GE Tomosynthesis**
- Step and shoot mode preserves microcalcification sharpness and avoids image blur, since the tube makes a complete stop for each of nine exposures
- Anti scatter solution designed for tomosynthesis, the SenoClaire grid in 3D reduces scattered radiation while preserving dose and performance
- SenoClaire uses ASIR®-A calcification correction reconstruction algorithm
V-Preview
A 2D image generated from the raw DBT projection data that helps the user get a overview of the entire stack of images before reading individual tomosynthesis images.

V-View

Unique Features of Siemens Tomo Unit
- Amorphous Selenium detector
- 50 degree acquisition of 25 projection images
- Continues tube movement
- 30 second acquisition
- Grid used for 2D Retracted for 3D
- 2 different compression paddles—reconstruction and spatial resolution do not depend on paddle used
Tomosynthesis

- Less expensive than CT or MRI
- Processes a 3D view that can detect breast cancers with a higher degree of accuracy
- Reduces false positives
- Up to 1.5% better detection
- Improves detection in dense breasts
- Reduces number of call backs for work up
- Studies are showing technology can not be underestimated

Differences in Scanning Angles

- Phillips/Sectra 11 degrees
- Hologic 15 degrees
- GE 25 degrees
- Siemens 50 degrees
- Fuji 15/40 degrees
- Number of projections 9-25

MQSA Facility Certification Extension Requirements

- Digital Breast Tomosynthesis system is a new mammographic modality
- Personnel requirements for new modality may apply
- Facility must apply to FDA to have its certificate extended to include that portion of the unit
- Facility must have the 2D portion of the unit accredited by one of the approved accreditation bodies
- A hardcopy of soft copy 3D phantom image must be submitted
- Mammography Equipment Evaluation must be included
- Information on vendor Quality Control Program submitted
- Attestation from Physicist on Personnel Qualifications
MQSA Facility Certification Extension Requirements

- NO IMAGES ARE SUBMITTED

Example-Anthem BC/BS

Position Statement
- Investigational and not medically necessary
- Digital breast tomosynthesis is considered investigational and not medically necessary for all indications
- Commission evaluated numerous studies

Centers for Medicare and Medicaid Services

- Effective January 1, 2015
- New reimbursement codes
- Two new CPT codes to be used as add-ons to existing G-codes when DBT is used with either screening or diagnostic full field digital mammography

Anthem BC/BS CONCLUSION

- There is evidence to suggest that use of mammography in addition to DBT may increase the numbers of cancers detected, which would then translate into a decrease in the number of females who undergo unnecessary recalls or breast biopsies. However, the published experimental and feasibility studies are unclear if DBT should be utilized for screening, diagnostic or surveillance purposes. Or if it should be used in lieu of or in conjunction with other imaging technologies. In addition to these issues, there are persistent concerns regarding radiation exposure, and the steep learning curve for radiologists to accurately interpret the DBT results.

Reality

- Medicare is reimbursing for digital breast tomosynthesis
- Other insurances are not reimbursing due to consideration that technology is investigational

TMIST: Tomosynthesis: Comparison of Full Field Digital with Digital Tomosynthesis

- Comprehensive study that compares DBT with full field digital mammography
- Limited clinical data on breast screening with tomosynthesis
- Multivendor, randomized clinical trial conducted at over 30 sites over a 5 year period
Primary aim will be to compare the number of advanced cancers defined as all tumors diagnosed as Stage II or higher and all tumors that are over 6mm in size and have markers that suggest they are aggressive.

Patient population will be asymptomatic women presenting for screening mammography who are at least 40 years old.

Study to enroll potentially 67,000 women split between two arms: digital mammography or tomosynthesis.

All women will undergo one test or the other for 3 consecutive years.

Injection is given using a power injector.

Lesions are visualized better with a higher concentration of iodine.

The woman can be seated during injection and breasts are not under compression.

Both breasts are compressed into desired projection.

Optimal imaging window is 2-8 minutes.

What is Contrast Enhanced Mammography?

A mammography examination that utilizes a contrast agent to enhance and highlight suspicious areas within the breast.

Why use contrast?

Contrast targets malignant areas and encompasses that area.

Uses an iodinated contrast.

Breast Density Software

Determines the density of the tissue.

It is the volume of the dense breast tissue divided by the volume of the breast and then multiplied by 100.

The breast density will be consistent and used to detect early breast cancers by picking the first sign of change.

Clinical Protocol

Injection is given using a power injector.

Lesions are visualized better with a higher concentration of iodine.

The woman can be seated during injection and breasts are not under compression.

Both breasts are compressed into desired projection.

Optimal imaging window is 2-8 minutes.

Potential Clinical Benefits

Alternative to Breast MRI

Evaluate difficult to interpret mammograms.

Patients contraindicated for MRI:

- e.g. claustrophobia or pacemakers
- Identify potential undetected malignancies.

Monitor effectiveness of drug therapy.

Identify potential undetected malignancies.
Dual Energy 2D Imaging

Two exposures occur in rapid sequence:
- Low kV (normal mammogram)
- High kV (~45-49 kV, Cu filter)

Subtraction gives a 2D contrast image
- Repeat as desired

Imaging window ends after ~8 minutes
- Due to contrast redistribution

Dual Energy 2D Combo Imaging

Three exposures are made in rapid sequence:
- Low kV tomosynthesis scan
- Low kV (normal mammogram)
- High kV (~45-49 kV, Cu filter)

Subtraction gives a 2D contrast image
- Repeat as desired

Imaging window ends after ~8 minutes
- Due to contrast redistribution
Ultrasound
• Began in the 1950’s
• Incorporated the use of A mode technology
• Immersion, compression, and contact transducers for sonographic breast imaging continued through the early 1960’s
• In the late 1960’s and early 1970’s, B-mode transducers with frequencies ranging between 1.5 MHz to 10.0 MHz produced images that could differentiate types of breast tissues

ACRIN 6666 ABUS Study
• 21 sites
• 2809 women (at least heterogeneously dense in one quadrant)
• Mammography and physician performed handheld full breast ultrasound
• Diagnostic yield of mammo vs. mammo plus ultrasound

Ultrasound
• Up until the early 2000’s, breast sonography was used to differentiate between solid and cystic masses.
• Today, breast sonography uses high-frequency, high resolution, real time systems.
• Transducers should be 10 MHz or higher
• ABUS-Automated Breast Ultrasound System

ACRIN 6666
• Physicians underwent consistent training
• 20 minutes avg. scan time plus interpretation
• Mammography alone 7.6/1000 cancers detected
• Mammography plus US 11.8/1000
• 12 cancers detected by US alone
The resulting 3D data is sent to the somov display console for review and rendering.

Reverse Curve Transducer
- Creates a uniform compression across the entire breast
- Enables a greater penetration due to the convergent scan line geometry
- Improves detail resolution at depth
- Anatomically correct

ABUS
- Automatically scans a woman's breast capturing multiple images
- Displays them in 3-D for a radiologist review
- Ideal for women with dense breasts where effectiveness of mammography may be limited
SonoCine AWBUS
Automated Whole Breast Ultrasound

Siemens
ACUSON S2000 ABVS-Automated Breast Volume

SonoCine – System
Use existing Ultrasound System

• The AWBUS™ articulating arm, which uses the transducer of your ultrasound system, provides whole breast coverage while still allowing the operator to adjust the angle and pressure of the transducer
Elastography

A non-invasive technique that adds value to the sonographic examination by evaluating the stiffness of tissue. It detects the stiffness or elasticity compared to normal tissue.

A small amount of pressure is applied to the breast, just enough to move it slightly.

With the pressure applied, the ultrasound system takes another image.

A computer then takes the two images and compares how elastic the different regions are.

A hard, inflexible lump is almost always a carcinoma. A flexible lump is usually benign.
Breast Density

- Has received a lot of attention lately
- Linked to an increase in cancer risk
- Need for accurate, reproducible density measurement
- Density has historically been measured by radiologists comparing the light and dark parts of the mammogram
- This method is operator dependent and is very subjective

Breast Density Challenges

- Challenge of determining breast density is that it is based on a 2D image as opposed to the breast actually being a 3 dimensional organ that varies in size, shape, and composition
- An area that appears almost white on a mammogram could be a single highly dense area or several densities overlying each other
- Density can be evenly distributed or the area near the skin could be dense while the center of the breast could be largely replaced by fatty tissue

PET

- Physiologic image to detect cancer or cancer therapy results
- Indicates if cells are active and growing or inactive and shrinking
- A molecule is tagged with a positron emitting isotope (Radioactive substances combined with a natural body compound)
- 18-F fluorodeoxyglucose (a probe)
- Radioactive 18-F tagged with a glucose
**PET Scan**
- Positrons annihilate nearby electrons, emitting photons
- Photons are detected by the scanner
- Cancer accumulates glucose more than normal tissue (glucose metabolism)
- Patient prep is required (fasting, limited exercise)
- 45-90 minutes rest post injection
- 30-45 minutes scan time

**PET Scan**
- High FP (esp. lobular and well differentiated Ca)
- High Cost: Cyclotron is needed near PET, isotopes are short lived (hours)
- Combine functional imaging of PET with anatomical imaging of CT

**PET Scan**
- Following a 4 hour fast, serum blood is drawn to determine blood glucose level
- 10mCi FDG is injected intravenously and imaging is acquired one hour later
- Imaging is obtained in a similar manner as mammography
- Breast is imaged with slight compression

**PET Scan**
- Nuclear medicine exam that uses intravenous injectable FDG (fluoro-deoxyglucose)
- A glucose analog that accumulates in glucose avid cells
- Accumulates in both inflammatory and cancerous states

**Naviscan**
**PEM**

*FDG* (fluoro-deoxyglucose) is a glucose analog that accumulates in both inflammatory and cancerous states.
PEM

- Reimbursed for:
  - Pre-surgical planning and staging
  - Monitoring for recurrence
  - Neo-adjuvant therapy
  - Equivocal exams following diagnostic workup

PEM Compared to Mammography

- Great value in preoperative identification of non-invasive breast cancer (DCIS)
- DCIS accounts for 30% of newly diagnosed patients
- DCIS is often difficult to quantitate with mammography and MRI
- Used for preoperative surgical staging

PEM

- Dose 1.4-7mSv
- Approx $800K purchase price
- Reimbursement is controversial
- $1000 - $2000
- Need to improve the markers (FDG) to improve sensitivity

Molecular Breast Imaging

- Scintimammography FDA approved 1997
- Traditional multi-purpose gamma camera
- Indicated for planar imaging to assist mammography
- No significant difference in detection fatty vs. dense breasts
- Limitation with lesions less than 1 cm
- Positioning an issue to image the entire breast
Scintimammography/Breast Specific Gamma Imaging

- Uses a radioactive tracer that "lights" up any areas of cancer inside the breast.
- Tracer is injected into the body through a vein in the arm.
- Breast cancer cells take up the radioactive substance much more than normal cells do.
- A nuclear medicine scanner that scans the breast looking for areas where the radioactive substance is concentrated.

MBI BSGI Scintimammography

- Imaging performed 5 minutes post injection.
- Breast is lightly compressed between 2 detectors.
- Images are obtained in cranial caudal and mediolateral oblique projections.
- Easily compared to mammography.

MBI-Sensitivity

- MBI has an overall sensitivity of about 90% with a sensitivity of 82% for lesions less than 10 mm in size.
- Sensitivity is lowest for lesions less than 5 mm in size.
- Tumor detection does not appear to be dependent on tumor type, but rather on tumor size.

Nuclear Medicine

- Holds special promise in determining cancerous lesions in dense breast.
- Use of scintimammography after abnormal mammogram offers higher level of diagnostic specificity.

Breast Specific Gamma Imaging BSGI

Brem study of 167 lesions in 146 patients:
- Sensitivity = 96.4%
- Specificity = 59.5%
- Purchase cost $240K
- Reimbursement $700-1200
BREAST MRI

Breast MRI

- Breast MRI the most rapidly growing segment of MR Imaging
- Improvements in MRI resolution, contrast, biopsy devices, CAD software
- American Cancer Society (ACS) recommendations published
- Clinical trials proved its worth (ACRIN 6667)

ACS Guidelines

- BRCA mutation
- First degree relative with breast cancer
- Lifetime risk 20-30% as defined by BRCAPRO or other models that are family history based
- Radiation to the chest age 10 – 30 yrs
- NOT dense breasts

MRI Screening

- 7 studies identified missed cancers
- Improved the cancer detection rate 10-40 per 1000 of the high risk women screened
- Average 22/1000
- Specific populations benefit
**Konen Breast CT**

- FDA approved January 14, 2015
- Alternative to mammography using cone beam technology
- Produces high resolution 3D of breast tissue without *compression*
- Hundreds of images are captured in a single 10-second rotation of the gantry and processed within seconds

**Applications**

- Konen Breast CT captures hundreds of low dose images of the entire breast during a short 10-second exposure without compression of the breast.
- Needle biopsy and localization with 3D targeting
- Evaluation of breast implants
- Response to neoadjuvent therapy
- Volume and density measurement
Based on the principle that chemical and blood vessel activity in both pre-cancerous tissue and the area surrounding a developing breast cancer is almost always higher than in the normal breast.

Since pre-cancerous and cancerous masses are highly metabolic tissues, they need an abundant supply of nutrients to maintain their growth.

This increases circulation to their cells by sending out chemicals to keep existing blood vessels open, recruit dormant vessels and create new ones.

This process results in an increase in regional surface temperatures of the breast.

**Breast Thermography**

- Uses ultra sensitive infrared cameras and sophisticated computers to detect, analyze and produce high-resolution diagnostic images of these temperature and vascular changes.

**Breast Thermography**

- Based on the principle that chemical and blood vessel activity in both pre-cancerous tissue and the area surrounding a developing breast cancer is almost always higher than in the normal breast.
**However**

- American Society of Breast Surgeons (ASBrS) conducted a study with results presented at their annual meeting in Phoenix in May
- The conclusion is—Thermography is not a reliable breast cancer screening tool

**Reason**

- Too many benign biopsies are performed based on suspicious imaging abnormalities
- Women are seeking an alternative to radiation based imaging techniques