

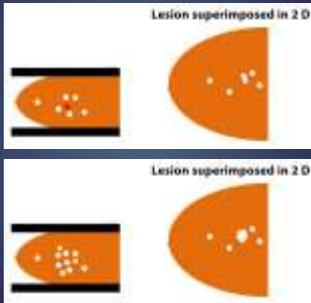
Digital Breast Tomosynthesis

OLIVE PEART MS, RT(R) (M)
HTTP://WWW.OPEART.COM

2D Mammography

- ▶ Not 100% effective
- ▶ Limited by tissue superimposition
- ▶ Overlapping tissue can mask tumors
 - ▶ False negative
- ▶ Overlapping structures can mimic tumors
 - ▶ False positive

False Negative...False Positive



Development

- ▶ Tomosynthesis first described in the 1960s
- ▶ The basic principles of tomosynthesis were reviewed 1971
- ▶ However DBT was not possible until the development of digital detectors in the early 1990s

1st Tomosynthesis Application

- ▶ Massachusetts General Hospital
 - ▶ First to prove DBT could be applied to evaluation the whole breast
- ▶ MGH partnered with GE to develop digital detectors
- ▶ In 1996, Mass General physicist Loren Niklason, PhD, and Dr. Kopans filed a patent entitled "Tomosynthesis System for Breast Imaging."
 - ▶ Described a digital breast tomosynthesis (DBT) system that had the tube moving across the breast

Development Technique

- ▶ Initial experiments
 - ▶ Imaged phantoms and mastectomy material by manually moving the x-ray gantry to collect projection images from different angles

DBT Options

- ▶ The x-ray tube may be moved while the breast and detector are held stationary
- ▶ The tube and detector may move
- ▶ The motion of the two can vary

1st DBT System

- ▶ GE Healthcare built the first whole-breast DBT system for US under grant BC970208 from the U.S. Army
- ▶ Flat panel digital detector
- ▶ 40° angle, 9 views
- ▶ The first volunteer patient was imaged in 1999



GE Healthcare

- ▶ Performed the first studies
 - ▶ Involved several hundred volunteers, beginning in 2000
- ▶ Showed that DBT was able to greatly improve the detection rates and reduce the recall rate

Limited-Angle Tomography

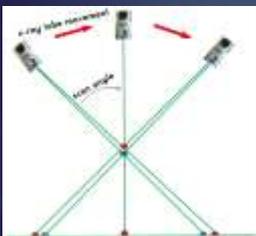
- ▶ DBT a form of limited-angle tomography
- ▶ Low-dose full field projection images of the breast obtained from different angles
- ▶ X-rays pass through the breast from different directions



Parallax

- ▶ Fundamental principle behind DBT takes advantage of parallax from the projection images obtained at varying angles
- ▶ The greater the angle through which the x-ray tube is moved, the better is the z resolution

Breast Tomosynthesis



- ▶ Structures located at different depth will project at different locations
- ▶ Structures closer to the detector will appear to move over a shorter distance when compared to structures that are farther away from the detector

Synthesize Planes

- ▶ After image acquisition
 - ▶ The computer aligns all of the projection images so that structures in the plane of interest all align precisely
 - ▶ Structures in the plane of interest are registered and reinforced by the number of projection images obtained
 - ▶ Structures not in the plane of interest are misregistered with one another and fade into the background

Shift And Add

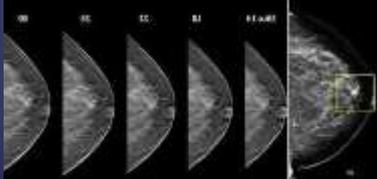
- ▶ The computer shifts the images and add them again to obtain a different plane
- ▶ All planes are synthesized through the entire breast from a small number of projection images
- ▶ The structures in each plane are more clearly visible without the interference of tissue in front or in back of the plane of interest

Synthesized Slice

- ▶ All of the projection images are included in every synthesized slice
 - ▶ The information is misregistered
 - ▶ Out-of-plane information fades into the background with the plane of interest reinforced as many times as the number of projection images obtained

Projection versus Reconstruction

- ▶ Sequence of projection images are acquired
- ▶ Projections are reconstructed in 3D volume



Reconstructed Volume

- ▶ The breast volume is reconstructed and displayed through planes parallel to detector surface



Dose

- ▶ Each projection image requires only a fraction of the total dose of a full 2D mammogram
 - ▶ Reason: All of the projection images are added together to synthesize the planes
- ▶ DBT can be performed at approximately the same total radiation dose used for 2D mammography

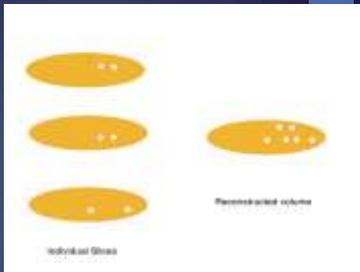
Pixel Manipulation

- ▶ To improve efficiency pixels are added together and averaged in some systems
 - ▶ Pixel Binning
- ▶ Results in:
 - ▶ Increased the pixel size
 - ▶ Reduced spatial resolution
 - ▶ Reduced visualization of calcifications

Imaging Calcifications

- ▶ A cluster of calcifications may not be easily perceived with DBT
 - ▶ Planes through the breast are presented as individual synthesized planes
 - ▶ One plane may reveal a single calcification
 - ▶ The next may contain two calcifications
 - ▶ The next plane one calcification
 - ▶ Consequently calcifications not visualized as a cluster

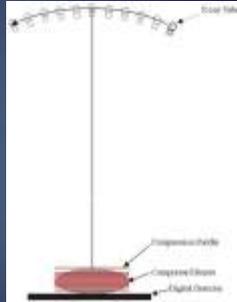
Slabbing



- ▶ Slices are slabbed together
- ▶ Offer better visualization of calcifications
- ▶ The clusters become apparent in the volume

Imaging

- ▶ Typically, the number of images acquired ranges from approximately 10 to 25
- ▶ Angle ranges from about 10 to 50°



Hologic Digital Tomosynthesis



- ▶ 15 exposures in 4 sec
 - ▶ Tube sweeps from -7 to 0 to +7
- ▶ The x-ray beam is continuously "on"
- ▶ No movement of the patient
- ▶ [DBT tomo.mp4](#)

Hologic DBT Stats

Tube

- ▶ Tungsten (W) Anode
- ▶ LFS: 0.3 mm; SFS: 0.1 m

Detector

- ▶ a-Se detector, 24×29 cm area
- ▶ 140 μm pixel size
- ▶ Reconstruction –
 - ▶ ~100 μm pixel size –1 mm thick slices
- ▶ NO GRID

Hologic DBT Stats

Filtration

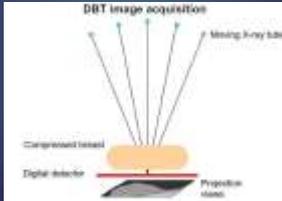
- ▶ Conv: 50 μm Rh; 50 μm Ag
- ▶ Tomo: 0.7 mm Al
- ▶ I-View: 0.3 mm Cu

Generator

- ▶ Max mA varies with kVp
- ▶ 20 -39 kVp for 2D
- ▶ 20 -49 kVp for tomosynthesis
- ▶ 200 mA max for LFS; 50 mA max for SFS

3D- Options

- ▶ The # of reconstruction images based on the breast thickness in mm



Slices

- ▶ Slice #1 is closest to the detector.
 - ▶ Highest slice # is closest to compression paddle
- ▶ Reconstruction is always in 1mm thick slices
 - ▶ A breast 4 cm thick = 40 mm
 - ▶ = 40 + 6 = 46 slices
 - ▶ A breast 5cm thick =50 mm
 - ▶ = 50 + 6 slices = 56 slices



Tomosynthesis and Motion

- ▶ Motion can occur at one point, multiple points or through-out the duration of the entire projection series
- ▶ Motion can occur at different areas of the breast, which may or may not impact breast tissue
 - ▶ Repeats for motion increase radiation dose
 - ▶ Potential to miss breast cancer

Factors Contributing to Motion Unsharpness

- ▶ Inadequate Compression
- ▶ Poor Positioning
- ▶ Exposure Time
- ▶ Patient Movement
- ▶ Heart Motion

2D vs 3D –Motion Unsharpness

2D Mammography

- Acquisition time is brief
- One image
- Technologists/ radiologists adept at detecting motion
- Repeats are left up to the Technologist

3D Tomosynthesis

- Longer acquisition time
- Multiple images acquired over a period of time
- **Motion may go undetected**

Appreciating 3D Motion: QC Review

- ▶ Projection Series
 - ▶ Most efficient way to detect motion
 - ▶ Review series at Selenia® Dimensions® System
- ▶ Tomosynthesis Reconstruction
 - ▶ More difficult to detect/confirm motion on reconstruction
 - ▶ Unsharpness in the tomosynthesis dataset
 - ▶ Non-linear movement of calcifications
 - ▶ Objects or lesions look sharp in one view, but not the opposing view

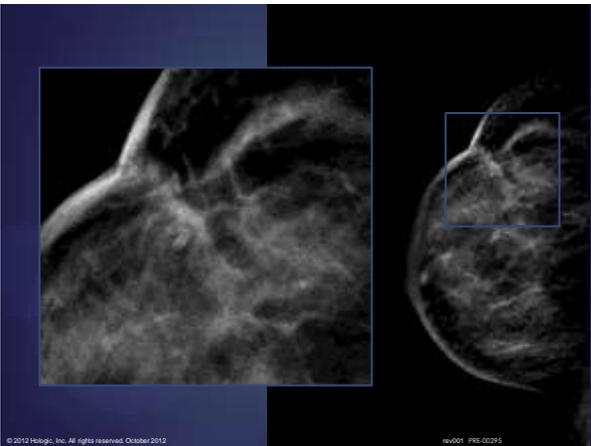
Tomosynthesis and Motion

3D Motion in the Hologic System may be unrealized and unchecked

- ▶ Radiologists do not routinely review the projection dataset where motion can be confirmed or ruled-out
- ▶ Projection dataset may not be available to the radiologist (BTO)

It is up to the technologist to detect motion and repeat when advised

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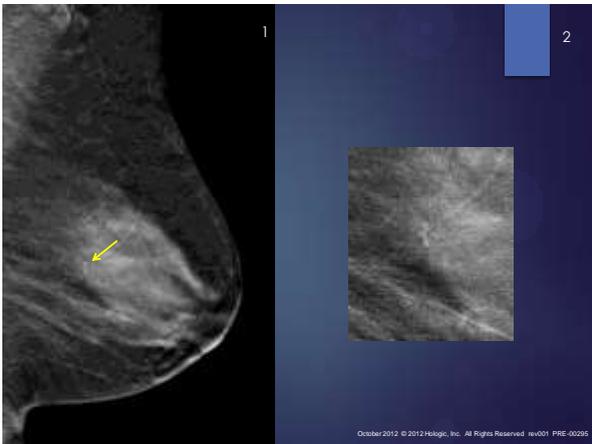
Appreciating 3D Motion

Projection Series

- ▶ The x-ray tube moves in a path parallel to the chest wall
- ▶ The resulting breast image(s) and objects should move smoothly along this same pathway
 - ▶ Medial to Lateral /Lateral to Medial
- ▶ Anterior/posterior movement of the breast images or objects indicates motion

Appreciating 3D Motion

- ▶ **Chest wall**
 - ▶ Movement of the Pectoral Muscle
 - ▶ Structures that shift in and out of view
- ▶ **Inframammary fold**
 - ▶ Abdomen motion
 - ▶ Determine if it impacts the inferior and posterior breast
- ▶ **Calcifications**
 - ▶ Should move in a straight line parallel to the chest wall
 - ▶ More evident with large chunky calcifications
- ▶ **Axilla**
 - ▶ Lymph Nodes shift back and forth or out of view



Reviewing Projection Images for Motion

- ▶ Review the 15 Projections
 - ▶ Cine Mode
 - ▶ Moderate to fast speed



Cine
Tools | Notices | Comments | Service | ROI



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Reducing Motion

- ▶ Inform the patient
- ▶ Describe tube movement
- ▶ Explain how motion will affect the image
- ▶ Instruct the patient in the breathing technique
 - ▶ Explain that **STOP BREATHING** means just that
 - ▶ Patient **SHOULD NOT** take in a breath & hold it

Breathing Technique

- ▶ Compress exposure controls
- ▶ While the x-ray tube is moving into position to start the tomosynthesis:
 - ▶ Instruct patient to **STOP** breathing for the 3D acquisition
- ▶ At the conclusion of the tomosynthesis sweep
 - ▶ Instruct patient to **breathe**
- ▶ As the tube moves to center, listen for the completion of the grid movement
 - ▶ Then instruct the patient to **stop breathing** for the 2D acquisition

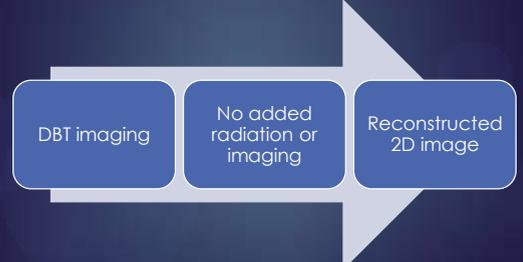
Image Acquisition Modes



- Conventional
 - Acquires 2D images only
- Tomo
 - Acquires tomosynthesis images only
- TomoHD
 - Acquires tomosynthesis images only
 - Produces C-View images
- Combo
 - Acquires 2D images
 - Acquires tomosynthesis images
- ComboHD
 - Acquires 2D images
 - Acquires tomosynthesis images
 - Produces C-View images

Hologic

C-View Option



```

    graph LR
      A[DBT imaging] --> B[Reconstructed 2D image]
      B --- C[No added radiation or imaging]
  
```

Generating 2D Images

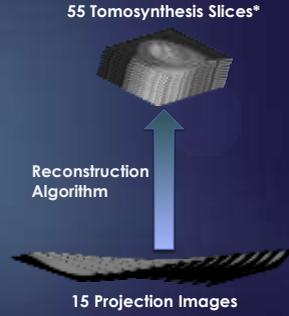
► Perform a standard tomosynthesis scan



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Generating 2D Images

- ▶ Perform a standard tomosynthesis scan
- ▶ Reconstruct tomosynthesis slices

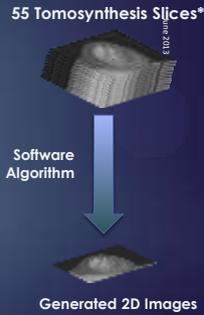


*Average slices based on 5 cm compressed breast

Hologic Proprietary - For Educational Use Only - rev002 PRE-00380

Generating 2D Images

- ▶ Perform a standard tomosynthesis scan
- ▶ Reconstruct tomosynthesis slices
- ▶ Synthesize 2D image
 - ▶ Available in any tomosynthesis projection

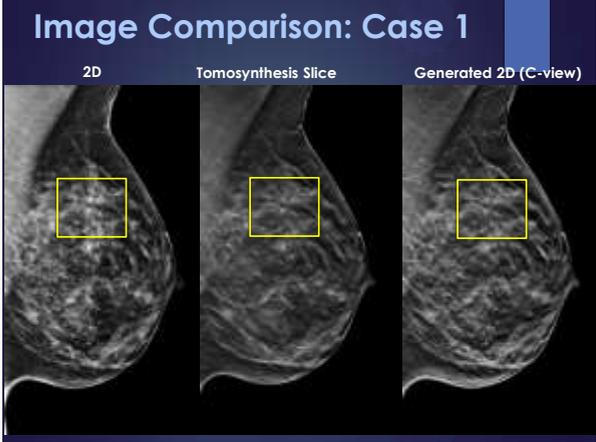


*Average slices based on 5 cm compressed breast

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Advantages of C-View

- Scan Time Reduction
 - 4 sec vs.12 sec
 - Lowers Risk of Patient Motion
- Patient Dose Reduction
 - 1.45 mGy vs. 2.65mGy



Radiation Dose

- ▶ The glandular dose deposited in any one region can vary considerably
 - ▶ Glandular tissue and fatty tissue distribution
 - ▶ Glandular tissue concentrated towards center of breast
- ▶ Mean glandular dose (MGD) or Average glandular dose (AGD) assumes a homogeneous mixture of adipose and glandular tissue surrounded by a layer of skin

Average Glandular Dose

- ▶ ESE for a typical single exposure
 - ▶ $\approx 800-1200\text{mrad}$ ($8-12\text{mGy}$)
- ▶ Glandular dose
 - ▶ $\approx 100\text{mrad}$ (1.0mGy)
- ▶ ACR recommends
 - ▶ 0.3 rad (300mrad or 3mGy) with a grid
 - ▶ 0.1 rad (100mrad or 1mGy) without a grid

Radiation Dose

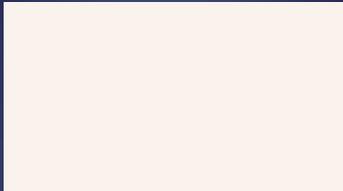
- ▶ 1.2 mGy – 2D
- ▶ 1.45 mGy – 3D
- ▶ 2.65 mGy – COMBO

- ▶ Imaging implants in 3D = more radiation to patient because lower kVp used

Drawbacks of Hologic DBT

- ▶ Motion artifacts hard to detect at radiologist workstation
 - ▶ Projection vs reconstruction images
 - ▶ Radiologist views reconstruction images
- ▶ Large number of images
- ▶ Degraded imaging of calcifications
 - ▶ Slabbing will help
- ▶ Tomo not possible for FB, Mag and if the breast is more than 24.5 cm
- ▶ Total exposure time for COMBO = 12 sec

GE SenoCare



- ▶ 9 exposures to acquire 3D MLO
- ▶ 25 degree scan angle
- ▶ Mo/Rh x-ray tube

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FDA Approved Sequence

- ▶ Two 2D CC
- ▶ Two 3D MLO
- ▶ Radiation dose similar to 2D mode
- ▶ In the step-and-shoot method after each image the movement resumes and x-ray tube moves to the next position



Comparison – GE & Hologic



- ▶ While the gantry moves the x-ray beam is pulsed
 - ▶ Results in longer exposure time (10 seconds)
 - ▶ More chance of patient motion

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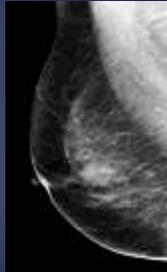
GE SenoCare Stats

- ▶ Image size
 - ▶ 24 x 30 cm
- ▶ Angular range
 - ▶ +/- 12.5
- ▶ Target/filter
 - ▶ Mo/Mo, Mo/Rh & Rh/Rh
- ▶ Filter material/thickness
 - ▶ Mo: 0.03mm Rh: 0.025mm
- ▶ kVp
 - ▶ Mo/Mo: 24-30 Mo/Rh: 26-32 Rh/Rh: 26-40



DBT and Grid Use

- ▶ Uses a step-and-shoot system
 - ▶ Eliminates focal spot motion blur
- Uses a moving grid
 - Offers improved image quality by reducing scatter



Imaging Calcifications

- ▶ Offers reconstruction of "slabs" (10 mm) and "planes" (0.5 mm or 1 mm) are reconstructed
- ▶ Uses ASIRDBT, an iterative reconstruction algorithm with a calcification artifact correction



Motorized Tomo Device



- ▶ 100 micron pixel size - no binning of pixels
- ▶ 5:1 Anti-Scatter grid
- ▶ Not available for Magnification, CESM, or negative angle exposures

Technologist AWS

- ▶ Only 9 acquired images available to review positioning
- ▶ Reconstruction takes place at Review Workstation



Drawbacks of GE SenoCare

- ▶ Motorized Tomosynthesis Device (MTD) attachment weighs over 12 kg (26.5 lb) and is not counterbalanced
 - ▶ Must be attached for TOMO
- ▶ Large number of images
- ▶ Face plate moves with tube

Attaching the DBT Device



Performing DBT



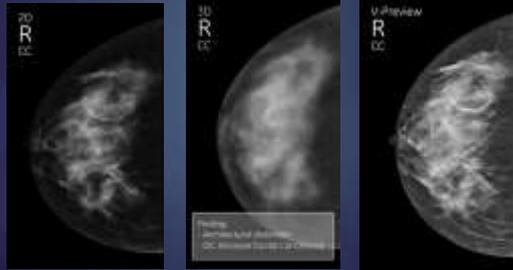
V-Preview

▶ 2D image generated from the raw DBT projection data set

▶ 2D

3D

V-Preview



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GE Senographe Pristina



- ▶ Digital detector technology: GEMS amorphous silicon matrix with CsI scintillator.
- ▶ Linear focused grid specially designed for mammography with Fiber interspaced
- ▶ Source to Image Distance (SID) of 660mm

Senographe Pristina Stats

- ▶ Dual track anode
 - ▶ Molybdenum
 - ▶ 0.03 mm Mo
 - ▶ Rhodium
 - ▶ 0.03 mm A
- ▶ Silver filter & Cesium Iodine detector
- ▶ Self-Compression



Self-Compression

- ▶ Handheld wireless remote control that patients can use to adjust the compression force after breast positioning



Senographe Pristina

- ▶ Operating kV-ranges
 - ▶ Mo/Mo: 22-32 kV
 - ▶ Rh/Ag: 27-40 kV
 - ▶ Mo/Cu and Rh/Cu: 40-49 kV
- ▶ Designed to support future functionalities
 - ▶ Contrast Enhanced Spectral Mammography
 - ▶ Biopsy
 - ▶ Mobile imaging

GE screening protocol

- ▶ 3D CC/MLO
- ▶ V-Preview CC/MLO
- ▶ When positioning for MLO the tube head can be moved to a parked position away from the technologist's head



Automatic Modes

- ▶ AEC operating mode of Senographe Pristina
 - ▶ AOP (Automatic Optimization of Parameters)
- ▶ AOP STD+:
 - ▶ Provides a higher image contrast to noise ratio (CNR) at the cost of a higher dose
- ▶ AOP STD:
 - ▶ Provides balanced CNR and dose choices,
- ▶ AOP DOSE-:
 - ▶ Delivers a lower dose at the cost of a reduced CNR

Siemens Mammomat Inspiration (PRIME & DBT)



- ▶ 50° Tomosweep (Continuous Scan)
- ▶ 25 projections
 - ▶ <25 sec
- ▶ W/Rh only
- ▶ Grid removed
- ▶ a-SE detector

Siemens

- ▶ MAMMOMAT Inspiration
- ▶ Offers the largest angular range -50°
- ▶ Highest number of projections images – 25
 - ▶ Results: 25 projections for 3D reconstruction
 - ▶ 50% dose by using the Tungsten/Rhodium



Siemens Stats

- ▶ 3 different dose levels: Mo/Mo, Mo/Rh, or W/Rh.
- ▶ Direct-to-digital amorphous selenium (aSe)
- ▶ High Detective Quantum



Other Options

- ▶ Individualized OpComp®
 - Stops compression automatically
 - Compresses only as long as a woman's breast is soft and pliable
- ▶ PRIME: Progressive Reconstruction Intelligently Minimizing
 - ▶ Exposure allows less dose without compromising image quality

Contrast Enhancement



Drawbacks of MAMMOMAT Inspiration

- ▶ Large number of images
- ▶ Face plate moves with tube
- ▶ Wide sweep



FujiFilm Aspire DBT



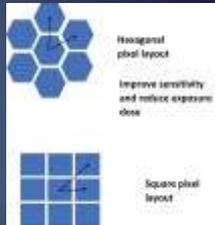
Target/Filter Combo

- Target/filter:
 - W/Rh and W/Al
- ▶ kVp range: 23-40
- ▶ mAs range: 2 – 600
- ▶ Focal Spot:
 - ▶ 0.1mm & 0.3mm
- ▶ Filter:
 - ▶ 50 µm Rh
- ▶ Grid:
 - ▶ 6:1, 40 lines /cm



FujiFilm Aspire Stats

- ▶ Tube current:
 - ▶ max 200mA
- ▶ Detector
 - ▶ aSe + TFT (hexagon pixels)
- ▶ Detector size:
 - ▶ 24 x 30 cm
- ▶ Output Pixel size: 50 µm
- ▶ Exposure time:
 - ▶ ST = less than 4 seconds
 - ▶ HR = less than 10 seconds



Fujifilm ASPIRE Cristalle

- ▶ The standard (SD) FFDM detector offers 3 Dose Modes
 - ▶ H-(High), N (Normal) or L (Low)
- ▶ Only N-Mode is Released in the United States
- ▶ DBT images of the breast are acquired in the ST (standard) DBT mode with N-mode dose setting only



Standard (ST) Mode

- ▶ Good for assessment of calcification clusters and general assessment of breast architecture
- ▶ AGD
 - ▶ 1.2 mGy for ST mode N-dose



FujiFilm Aspire DBT

- ▶ HR mode image can visualize spiculation and marginal structure of tumor clearly due to higher depth resolution and higher plane resolution.
- ▶ ST mode offers less depth resolution when compared with an HR mode image
- ▶ The depth directional structure of lesions such as microcalcification is superior in ST mode.
- ▶ Processing:
 - ▶ Pattern 1 enhances spiculations and calcifications while keeping maximum contrast for the viewing of masses within the glandular tissue.
 - ▶ Pattern 2 maximizes the visualization of fine spiculations and calcifications.

DBT Imaging

- ▶ DBT images are displayed individually or dynamically in a cine mode.
- ▶ The angular range is ± 7 degrees (15 degrees total)
 - ▶ 4 sec exposure time
 - ▶ Slices are 1-mm thick
- ▶ Continuous tube movement
 - ▶ 15 pulsed low dose exposures
 - ▶ Slice range compression thickness + 5 mm
 - ▶ Good for assessment of calcifications

Compression System

- ▶ Automatic compression
 - ▶ 50N to 200N
- ▶ Manual compression
 - ▶ 0N to 200N
- ▶ The images are acquired and reconstructed into a series of high-resolution 1 millimeter slices



Compression plate compression



Automatic Exposure Control

- ▶ Intelligent AEC (iAEC) auto mode:
 - ▶ kVp selected based on compression thickness, mAs determined by pre-exposure
- ▶ Semi-Auto:
 - ▶ kVp selected by user, mAs determined by pre-exposure
- ▶ Manual:
 - ▶ all factors set by user



Radiation Dose

PMMA Thickness (mm)	AGD (mGy)
▶ 20 mm	1.0 mGy
▶ 30 mm	0.9 mGy
▶ 40 mm	1.3 mGy
▶ 45 mm	1.6 mGy
▶ 50 mm	1.7 mGy
▶ 60 mm	2.6 mGy
▶ 70 mm	3.2 mGy

Thank You!