Breast Tomosynthesis: Benefits vs. Barriers

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Disclosures

• I have no disclosures.
Objectives

• Background of tomosynthesis
• Principles of tomosynthesis
• Comparison of DBT systems
• DBT dose factors
• DBT image artifacts
• Future of DBT
Questions of Interest

• Why should we be interested in DBT vs DM?
• Why DBT at this time?
• How do different vendors compare?
• Is DBT dose higher?
• What are the disadvantages?
• Are there unique image artifacts?
• Will DBT replace DM?
Glossary

- **2D**-two dimension mammography- film or digital
- **3D**- three dimension, applied but tomo is really not 3D.
- **Cesium Iodide**- radiation detection material used in indirect conversion x-ray image acquisition
- **DBT**- digital breast tomosynthesis
- **DM**- digital mammography
- **FFDM**- full field digital mammography
- **Selenium**- radiation detection material used in direct conversion x-ray image receptors
- **Tomosynthesis**- combines digital image acquisition and processing with simple tube/detector motion. Some similarities to CT tomo is a separate technique-
Breast cancer- perspective

• Most common form of cancer in women
• 2\textsuperscript{nd} leading cause of cancer death in women after lung cancer
• Chances of breast cancer increases with age
• Approximately 180,000 new cases each year
• 5 year survival rate is 98% if detected in its earliest stage
Breast cancer detection

• Mammography is gold standard. High contrast from normal and cancer tissues. Detects calcifications.
• Ultrasound useful for cyst vs solid, biopsy guidance, operator dependence. Evaluation of dense breasts.
• MRI useful for implant evaluation, high contrast sensitivity, breast cancer staging, high risk screening
Mammography evolution

• Mammography introduced in 1950s
• Xerography 1970s and 1980s
• ACR mammography accreditation in late 1980s
• MQSA 1992
• FFDM in early 2000s
• DBT in early 2010s
Why DBT?

• Breast imaging requires extremely high spatial resolution.
• Images must be obtained at low dose.
• High contrast of small structures, such as calcifications, spiculations, and lesion margins, requires the use of low-energy x-rays.
• Tomosynthesis allows the use of low-energy x-rays, low dose, and high resolution needed for breast imaging while also reducing superimposed structures.
Increasing cancer detection rates

• An effective screening program must not only limit false positives; it must identify true positives.
• With tomosynthesis, large-scale studies have demonstrated increased rates of cancer detection by approximately 30-40%, with the addition of tomosynthesis to conventional mammography.
• Most findings dramatic for architectural distortion, whether as a solitary finding or in association with a mass.
Why should we be interested in DBT?

Benefits of DBT

Studies show the following:

• Less superimposition
• Screening can miss 20-30% of cancers
• DBT increases sensitivity in dense breasts by 7%
• DBT increase lesion detection vs. DM by 7%
• DBT improves lesion localization
• DBT improves visualization of lesion margins
• DBT reduces recall rates
X-Ray source images

• **2 types**: continuous motion and step and expose.

• **Continuous motion**: the x-ray source moves at a constant rate of speed and the x-rays are pulsed on and off at specific angles.

• The motion of the tube during image acquisition can lead to image blur. Vendors typically use very short pulses on the order of 50 milliseconds or less to minimize this source of image blur. This requires higher power x-ray sources to obtain these short pulses.

• **Step and expose motion** is performed by physically stopping the x-ray source before each projection image is acquired and then moving to the next angle position after the exposure is complete. Motion from x-ray source motion can be eliminated using this method.
Tomosynthesis Acquisition

- X-ray tube moves in an arc around the breast
- Series of low dose images are acquired at different angles
- Total dose similar to standard breast exam
Acquisition

• Angle range of 15 to 50 degrees.
• Wider angle acquisition reduces the amount of superimposed tissue that may be present in the reconstructed tomosynthesis images.
• If the tomosynthesis acquisition angle was increased to slightly greater than 180 degrees, a true CT image could be obtained, resulting in complete removal of superimposed tissue.
• Tomosynthesis images acquired at 50 degrees may have reduced superimposed tissue compared with those obtained at 15 degrees.
• Narrow acquisition angles benefits includes better depiction of calcifications.
Image acquisition - critical parameters

- Detector
- Sweep angle
- Number of projections
- Scan time
- Relative dose
Acquisition time

- 4 to 25 seconds.
- Imaging angle, the number of projection images, and the type of tube motion all affect the time required to acquire the projection images.
- Shorter times will result in less patient motion during image acquisition.
- This may be a critical factor for visualization of small lesions, calcifications, and lesion margins.
Number of projection images

- Current systems use between 9 and 25 projection images.
- Images are then reconstructed into the tomosynthesis images.
- Artifacts are inversely related to the number of projection images.
Effect of Sweep Angle

- 2D
- 15° Sweep
- Narrower Sweep
- 50° Sweep
- Wider Sweep

versus
Radiation dose

• Radiation dose from tomosynthesis is approximately the same as that from mammography.

• If both a conventional mammogram and a tomosynthesis image are acquired—something often referred to as combo imaging—then the dose for a screening exam would be 2 times that used for mammography alone.

• Important to put this dose in perspective. The radiation dose from a mammogram is approximately equivalent to the amount of radiation from 1 month of background radiation. A CT exam may be equivalent to several years of background radiation.

• The FDA has determined the benefit from tomosynthesis combined with mammography outweighs the increase in radiation dose.
Radiation Doses in DBT

- Each individual DBT “projection” is very low dose
  - Hologic approach of acquiring DBT + 2D in both CC & MLO projections has a total dose that is about 2.0-2.5 x the dose of 2-view DM
  - Newer Hologic approach of acquiring only DBT views and reconstructing synthetic 2D views (C-view) has a total dose that is 1x-1.5x times that of DM
  - For GE, dose for a DBT view ~ dose for a 2D view
  - For Siemens, single-view DBT dose is 1.4 – 1.9 x higher than single-view DM dose, depending on breast thickness (bigger difference for thinner breasts)
Factors affecting dose

• Speed (efficiency) of the imaging system
• Preferred image density
• Breast thickness
• Breast density
• kVp selected. i.e. high kVp better penetration, high kVp lower contrast, high kVp lower dose
• Filtration used: Mo, Rh, or W
• Presence/absence and type of grid
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Common and unique DBT image artifacts

Common to DBT and FFDM:

- Detector failure modes
- Detector non uniformity
- Image processing
- Ghosting- long term and short term
- Collimator errors
- Patient motion
- Display monitors
DBT artifacts - unique

• Blurring of adjacent out of plane objects, zipper artifact
• Truncation at edges of the detector
• Persistence of objects from plane
• Related to tube motion
• Related to number of projection images
Skin artifacts

• Because moles and other skin lesions are seen so well on tomosynthesis, mole markers are not routinely required and may be distracting due to associated tomosynthesis slinky artifact.

• Positioning artifacts such as skin folds, hair, or a nipple out of profile can almost always be easily dismissed as benign.
Motion artifacts

• Motion artifact can sometimes be difficult to assess on tomosynthesis.
• All tomosynthesis images have inherent blurring appearance because out-of-plane objects are blurred due to out-of-plane signals.
• Gross motion may be determined by viewing the projection images in cine mode, paying attention to the periphery of the breast, specifically the skin of the axilla or the inframammary fold on the MLO view or the cleavage area on the CC view.
Motion artifacts

• If motion occurred during the tomosynthesis exposure, the skin in these regions will appear to bounce or wiggle.

• Motion should also be suspected if a slinky artifact is not in a straight vertical direction and instead is curved or V.

• Motion should also be considered if a mass or microcalcification is not as sharp as expected when in plane on the tomosynthesis slice.
Processing artifacts: processing error and dead pixel artifact

• Tomosynthesis processing error due to failure of the reconstruction algorithm can result in a horizontal linear artifact through the image.

• Skin processing reconstruction errors will make the superficial tissue and/or skin line difficult to visualize, resulting in an image with the appearance of an exposure problem.
A dead pixel artifact will usually result in a small white dot on the 2D and on the first tomosynthesis image, since the dead pixel is located on the detector. Because the dead pixel is on the detector, this artifact will appear on every 2D view in the same location. On the tomosynthesis images, the dead pixel will appear as a very fine slinky artifact.
Barriers to DBT

- More complex/time consuming to perform
- More complex/time consuming to interpret
- Increased maintenance costs
- Clips and large masses may persist across several slices
- DBT QC is more complicated
- Large increase in PACS storage and transmission time
Barriers to DBT

• Increases reading time but decreases recall rates
• Detects smaller cancers but does not increase detection of DCIS
• The cost of a tomosynthesis unit is more expensive than a 2D full-field digital mammography (FFDM) unit, by as much as 50%.
• For many facilities, the issue of conversion speed is a primary factor. Depending on budget considerations, some practices may be able to convert all at once, while others have to transition slowly, working in a hybrid setting of both tomosynthesis and FFDM as additional units are procured over time.
Barriers to DBT

• There are specific room size requirements to house a tomosynthesis unit, with a minimum of $12 \times 12$ feet required—larger than that required for an FFDM unit.

• This may mean that existing room space may need to be altered to install tomosynthesis units, which increases overall implementation costs.
Barriers to DBT

• Tomosynthesis datasets are large. A combination FFDM-tomosynthesis exam consists of three components: 2D FFDM, tomosynthesis source projection images, and reconstructed (1 mm) slice images (the number of which depends on breast thickness).

• This file size is about 10 times the size of FFDM.

• Due to the larger file size, storage needs to dramatically increase and must be budgeted accordingly.

• How images will be stored? Storage with 4:1 loss-less compression is recommended such that images can be adequately retrieved without loss of information.
Barriers to DBT

• Large image size is also important when considering transfer of images. For off-site satellite locations or multiple sites, transferred to and from a centralized location, adequate bandwidth is necessary.

• Adjustments may be needed to increase bandwidth to accommodate the large file size of tomosynthesis images.

• While increased image storage is an important consideration with tomosynthesis, storage capacities and options have greatly increased in recent years and are becoming less expensive over time, such that most facilities should be able to accommodate the increased demands without significant difficulties.
Barriers to DBT

• Workflow must also be considered: How many prior exams will generally be desired for comparison purposes?
• This choice affects the radiologist’s hanging protocol as well as image retrieval prior to patient appointments and becomes a more significant consideration after multiple years of imaging with tomosynthesis have accrued.
• The advantage of tomosynthesis to increase both sensitivity and specificity of mammography may depend on appreciating subtle changes compared to prior studies.
Barriers to DBT

• There are other factors to consider, such as having adequate random access memory (RAM) on the workstations. Some monitors might be too old to adequately display tomosynthesis studies.

• If the display speed is not sufficient, it will result in “jumping” while scrolling through the tomosynthesis slices.

• Other considerations entail having updated server hardware (this should be discussed with the PACS vendor) and network considerations.
Barriers to DBT

• Variable length of time for interpretation has been reported in the literature, with the majority of facilities reporting times that are approximately twice as long as FFDM alone.

• This may decrease slightly with experience, but will always remain longer due to the increased volume of images to review.

• It is important to recognize, however, that the increased time required to read individual cases is balanced by both the decreased number and markedly abbreviated diagnostic work-ups associated with tomosynthesis.
Who should have DBT?

• Many facilities choose to perform tomosynthesis for screening patients because this centers on the key benefits of recall reduction and increased cancer detection, as well as being available to the greatest number of patients.

• Other facilities choose to use it in the diagnostic setting, where there will be fewer exams, and permit radiologist experience to be gained in a more controlled environment.

• Others preferentially target specific patient populations who will likely benefit most, such as women with personal history of breast cancer/post-lumpectomy, those with dense breast tissue, women at high risk for breast cancer, and baseline screening patients.
DBT and dense breasts

• There is evidence that the use of supplemental sonography screening can increase cancer detection in women with dense tissue.

• However, the additional cancer yield on such supplemental exams performed after tomosynthesis is less compared with after 2D mammography.

• There is no question from current studies that tomosynthesis increases the accuracy of mammography in women with dense tissue.
How does DBT contribute to the work-up?

- When the lesion is obvious, the diagnostic work-up can usually begin with targeted ultrasound.
- In such cases the routine views with tomosynthesis provide sufficient information regarding lesion location and features such that spot compression and 90-degree true lateral views are not necessary.
How does DBT fit into the work-up?

• The diagnostic work-up will also differ depending on whether the patient originally underwent a 2D screening mammogram versus a tomosynthesis screening study.

• When a mass or architectural distortion is well seen on a 2D screening mammogram, full MLO and CC tomosynthesis views may be sufficient to assess lesion margins and helpful to evaluate the remainder of the breast for any 2D occult lesions.
How does DBT contribute to the work-up?

• If a lesion is subtle on both 2D and tomosynthesis, a diagnostic work-up is helpful prior to targeted ultrasound.

• Unlike a conventional diagnostic work-up in which spot compression is often performed in two views, a single tomosynthesis spot compression view usually suffices to distinguish between tissue overlap versus a true lesion.

• Single view only lesion evaluation. With the ability to localize a lesion within single, thin sections of breast tissue, tomosynthesis can eliminate the need for additional diagnostic work-up of lesions initially seen in only one view.
DBT and margin assessment

• Helpful in resolving the true margins of a mass.
• If the margins remain irregular or indistinct after overlapping tissue is cleared, these masses are suspicious and recalled.
• In many cases a spiculated margin may only be seen on the tomosynthesis images.
DBT and margin assessment

- Multiple, bilateral, circumscribed masses may also be plainly visible after layers of breast tissue are scrolled away.
- Multiple cysts or fibroadenomas that were previously unrecognized without tomosynthesis are not uncommonly encountered.
- Do not require recall unless a dominant or otherwise suspicious mass is present among the other benign-appearing masses. Rule of multiplicity.
- Overlapped, looped, or tortuous blood vessels may simulate a mass on conventional 2D imaging.
- The corkscrew nature of the looped vessel may be clearly seen when scrolling through tomosynthesis images.
DBT and the work-up of asymmetries

• Asymmetries recalled from a 2D screening mammogram can often be clarified by obtaining full combination 2D mammography and tomosynthesis in the same view(s) the asymmetry was initially seen.

• If the finding persists, further evaluation can be performed with ultrasound, obviating the need for spot compression views.
DBT and the work-up of calcifications

- Suspicious calcifications recalled from a 2D mammogram usually require standard magnification views.
- In these cases, tomosynthesis can be helpful if an associated mass is suspected.
Second look after two-dimensional mammography or ultrasound

• When a suspicious lesion is initially identified with 2D mammography and/or ultrasound, tomosynthesis may help to evaluate the extent of disease.

• Tomosynthesis may demonstrate multifocal or multicentric disease, which is occult on 2D mammography.

• Patients with highly suspicious lesions or newly diagnosed breast cancer who have so far only undergone 2D mammographic imaging may benefit from tomosynthesis to help to define the extent of disease prior to surgery.
Second look after magnetic resonance imaging

• In the setting of a suspicious MRI-detected lesion, targeted ultrasound is often the next best second-look modality.

• A sonographic correlate is identified in approximately half of cases.

• It may be possible to identify a mammographic correlate on tomosynthesis sections.

• A second-look tomosynthesis study may be helpful in patients with a suspicious MRI-detected lesion who have no sonographic correlate, particularly if initial imaging consisted only of 2D mammography.
Tomosynthesis-detected lesions with no ultrasound correlate

• Most suspicious masses seen on tomosynthesis have an ultrasound correlate, allowing ultrasound-guided biopsy to be performed for histologic diagnosis.

• Suspicious architectural distortion or focal asymmetry will occasionally not have an ultrasound correlate, making the diagnostic work-up problematic if the lesion can only be seen with tomosynthesis.

• Tissue sampling can be achieved with tomosynthesis-guided core needle biopsy or wire.
Tomosynthesis-detected lesions with no ultrasound correlate

- MRI may be helpful. If a corresponding enhancing lesion is identified on MRI, tissue sampling with MRI-guided core needle biopsy can be performed.

- It must be noted that, despite the high negative predictive value of MRI, there are currently little data to support imaging surveillance in lieu of tissue sampling of suspicious findings seen on tomosynthesis which do not have an MRI correlate, particularly a worrisome architectural distortion.

- Until further data is available, histologic sampling of suspicious lesions seen only on tomosynthesis remains standard practice.
Future of DBT?
NCCN Guidelines 2016

• August 1, 2016 -- New guidelines published by the National Comprehensive Cancer Network (NCCN) recommend that physicians consider digital breast tomosynthesis (DBT) exams as an option for their patients' annual breast cancer screening.

• The NCCN guidelines, published in "NCCN Clinical Practice Guidelines in Oncology: Breast Cancer Screening and Diagnosis," were developed and updated by an impartial, physician-led group consisting of 48 individual panels and comprising more than 1,150 clinicians and oncology researchers from the 27 NCCN member institutions.

• The guidelines were approved with uniform consensus (Category 2A) and state that "multiple studies show a combined use of digital mammography and tomosynthesis appears to improve cancer detection and decrease callback rates. Of note, most studies used double the dose of radiation. The radiation dose can be minimized by synthetic 2D reconstruction."
Surveillance after primary breast cancer treatment

• Evidence review supports the use of mammography for surveillance after primary breast cancer treatment. Variability exists in guideline recommendations for surveillance initiation, interval, and cessation. DBT offers the most promise as a potential modality to replace standard digital mammography as a front-line surveillance test; a single published study to date has shown a significant decrease in recall rates compared with standard digital mammography alone. Most guidelines do not support the use of whole-breast ultrasound in breast cancer surveillance, and further studies are needed to define the characteristics of women who may benefit from MRI surveillance. The emerging evidence about surveillance imaging outcomes suggests that additional factors, including patient and imaging characteristics, tumor biology and gene expression profile, and choice of treatment, warrant consideration in selecting personalized posttreatment imaging surveillance regimens.

Thank you.

Especially to all mammography technologists for what you do every day for our patients.