Digital Breast Tomosynthesis Fundamentals
For nearly half a century GE Healthcare has worked closely with numerous breast imagers with a single objective in mind:

**To develop accurate, efficient and patient friendly breast imaging solutions to enable early detection & early health.**

With the first launch of a digital flat panel system in the year 2000 GE Healthcare opened the doors to a range of new technologies and tools for mammography.

Digital mammography has become the new standard of care for early breast cancer detection\textsuperscript{1,2}. Despite all the advantages that have been gained in the past years with digital mammography, there are still some limitations in today’s approach.

It has been documented that around 22% of the malignant lesions, especially in dense breasts, are missed today\textsuperscript{3}. One possible reason for that could be that lesions or other anatomical structures may be hidden by superimposed tissues and could limit the radiologists’ ability to detect them.

By utilizing volumetric imaging that is already used in other modalities such as CT and MR, the images produced could help to avoid the problem of the overlapping tissue.

Digital Breast Tomosynthesis (DBT) is an example of a volumetric breast imaging technology.

Tomosynthesis takes a series of low dose X-ray exposures at different angles. Each exposure in the series is called a projection image. The generated data is reconstructed and displayed as multiple images of different planes of the breast, with all the projection images contributing to each plane.

GE Healthcare is working with numerous worldwide clinical researchers in order to evaluate the potential benefits of this technology.

Availability of GE tomosynthesis technology depends on the ongoing clinical trials, to then proceed accordingly with the appropriate local regulatory authorities, e.g. US FDA, CE marking.

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**Figure 1:** In Standard 2D mammography > Lesions can be hidden by superimposed normal structures.
Tomosynthesis is a three-dimensional imaging technology (3D imaging) that uses a low dose limited angle around the standard compressed breast, in order to generate a series of tomo-planes planes that are virtually free of overlapping tissue.

The acquired projection images are processed electronically in order to reconstruct a 3D representation of the entire breast, formed by a set of tomo-planes.

Each plane represents a virtual cut of the compressed breast, parallel to the detector, where the in-plane structures are sharply rendered and the objects from the other planes are blurred out.

Figure 2 shows two different tomo-planes, one through the spherical object and the second one through the cubic object. Both are reconstructed by shifting and adding the projection images. This describes the basic principle of digital tomosynthesis.
While the basic principle of tomosynthesis is the same for every device, the technologies that have been developed and implemented by various companies and researchers may be different, impacting the image acquisition process.

It has been shown that there are some key technical parameters that have a strong effect on the image quality of tomosynthesis:

1. Step & Shoot tube motion
To preserve microcalcification’s sharpness and to avoid image blur, step and shoot tube motion is the natural choice, with the tube making a complete stop for each exposure. It was demonstrated that step & shoot tube motion provides higher peak contrast for microcalcifications than the classical continuous tube motion.

2. Sweep angle range and number of projections:
It is essential to determine the right parameters for an angle aperture because a very wide angle may produce blurs in microcalcifications, and a very narrow one will preserve microcalcifications but with a poor separation of glandular overlaps and masses. Investigations have demonstrated that an angular sweep of 25 degrees and a series of 9 low dose exposures are well suited for SenoClaire (the brand name of GE Breast Tomosynthesis).

3. Detector performance at low dose
In order to keep the patient dose as low as possible when performing a Tomosynthesis examination it is necessary to choose an efficient detector, which has a high DQE at low dose. GE Healthcare’s detector offers a high DQE at low dose allowing the visualization of small objects such as microcalcifications. The resulting high SNR and the high speed read out capability of the detector allow the system to operate at the same small pixel size (100µm) as in 2D digital mammography.

A lower DQE detector would require other process to overcome signal/noise limitations, such as the addition of pixels or “binning”. The advantage in signal level is offset by a trade-off in spatial resolution because of doubling pixel sizes, compared to 2D.

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Figure 5: The significant advantage in the electronic noise factor allows the CsI-based detector to maintain its high DQE even at ultra low exposure levels (0.5 mR). Based on GE internal testing.
Factors impacting Digital Breast Tomosynthesis (DBT) Image Quality

### FFDM IQ Drivers

- Radiation Dose
- Beam Quality
- Detector Properties
- 2D Image Processing
- Image Display

GE's detector offers a high DQE at low dose that does not require this kind of tradeoff and therefore it allows the visualization of small objects such as micro calcifications. In addition it offers a large operating temperature range.

GE Healthcare’s a-Si/Csl independent conversion technology provides the same detector scanning at 100 micron (pixel size / resolution) for both 2D and 3D.

### Additional DBT IQ Drivers

- Step and Shoot tube motion
- Sweep Angle range
- and Number of projections
- Detector performance at low dose
- Distance between tomo-planes
- Reconstruction Algorithm
- DBT anti-scatter grid

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4. **DBT anti-scatter grid**
X-ray scatter is equally detrimental to image quality in 2D and 3D, particularly for large breasts, as it decreases the signal difference-to-noise ratio (SDNR) of projection views. Just as in FFDM, SenoClaire comes with an anti-scatter solution designed for tomosynthesis. The DBT compatible grid both enhances image quality for thick breast in 3D and greatly contributes to preserving the same dose as 2D.

5. **Reconstruction algorithm**
GE Healthcare uses an iterative reconstruction algorithm, called ASiR DBT. This reconstruction yields images that are FFDM-like, easy to interpret, and with reconstruction times equivalent to transfer times. This reconstruction method has a mechanism that positively impacts overlapping microcalcification conspicuity versus classic Filtered Back Projection (FBP) algorithm.

Not all the tomosynthesis systems are built & designed the same way, they work in different ways, and clinical outcome may be different.

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As tomosynthesis is multiplying the number of images per view, (for a 60mm breast thickness at one image every 0.5 mm, the total number of images for one view will be 120), it is extremely important to evaluate and design the Workflow.

Some additional important requirements are related to the workflow and productivity of tomosynthesis.

- Positioning and acquisition time
- Reading time
- Data storage & transmission
- Reimbursement

**Patient positioning and acquisition time**
The positioning of the breast in tomosynthesis is performed the same way as in today’s mammography (2D) procedure. A very efficient procedure is the following:
- The breast is compressed in a normal MLO position.
- The tube rotates over an angle of 25 degrees around a stationary detector.
- The X-ray tube applies 9 low dose exposures.
- The data from the 9 acquired projections are immediately transmitted to the reconstruction computer, where the breast volume is reconstructed in 0.5 mm spaced tomo-planes, which are sent to the radiologist's review workstation.

**Data storage & transmission**
Both the online storage capacity and the long-term storage capacity need to be evaluated when performing tomosynthesis applications as the image volume is multiplied (> 10 times). The extended data set requires a fast data transmission in order to enable an acceptable preview and image storage time. GE tomosynthesis images are compatible with major PACS providers (with local variability), allowing integration into your environment and helping you make optimal use of your investment.
Summary and outlook

While tomosynthesis clinical results indicate its potential to enhance breast imaging, there are still many open questions that require further investigation. For it to be effective, usable and as safe as FFDM, some key challenges must be addressed:

- Total patient dose
- Angular sweep range and number of projections
- Reconstruction time and image display
- Workflow
- Acceptable reading time
- Storage requirements
- Quality control for 3D.

Multi-center clinical study

GE Healthcare conducted a multi-center clinical trial with renowned breast radiologists, in order to evaluate the tomosynthesis procedure.

GE Healthcare designed the Senographe with upgradability in mind, you can easily expand the system as your needs and capabilities grow. SenoClaire 3D breast tomosynthesis, stereotaxy, or SenoBright contrast enhanced spectral mammography are fully compatible with any Senographe Essential and Senographe Care. It’s an excellent balance of precision and performance, so you can be confident in your investment.

Figure 7: LMLO image (zoomed), Senographe 2D image.

Figure 8: LMLO image (zoomed), SenoClaire tomo-plane.

Figure 9: Images from Oncological Institute of Veneto, Padova, Italy.
References
8. Daniel B.Kopans, MD, F.A.C.R., Professor of Radiology Harvard Medical School, Senior Radiologist – Breast Division Massachusetts General Hospital, Digital Breast Tomosynthesis.

Glossary
2D Two-dimensional
CT Computed Tomography
MR Magnetic Resonance
US FDA US Food and Drug Administration
CE Marking A mandatory European marking for certain product groups to indicate conformity with the essential health and safety requirements set out in European Directives
3D Three-dimensional
DQE Detective Quantum Efficiency- A measure of the dose efficiency of a detector
SNR Signal to Noise Ratio
Tomo-plane A cross-section in mathematical volume created from the retro-projections of the projection views. They are the geometric planes for which the source motion and image shift compensate each other exactly, yielding a focused image only from the points belonging to that plane.
FBP Filtered Back Projection
FFDM Full Field Digital Mammography
IQ Image Quality
DBT Digital Breast Tomosynthesis
MLO Mediolateral Oblique
CC Craneiocaudal

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