Application of the draft EUREF protocol for Quality Control of digital breast tomosynthesis (DBT) systems

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Quality Control Protocol

- EUREF group has produced a draft protocol
  - Latest version 0.14 sent in February 2014
  - Gives the scope of the protocol, defines DBT systems and gives tests for quality control of DBT systems

- North American guidance
  - AAPM TG 245 Task Group on Tomosynthesis Quality Control

- IEC standard in preparation
Outline of protocol

- DBT protocol assumes that standard FFDM tests are performed prior to DBT tests

- DBT tests broken down by component in the protocol
  - X-ray generation
  - AEC system
  - Image receptor
  - Image quality of the reconstructed image
  - Dosimetry for DBT systems
Typical geometry for DBT systems

- Tube rotates over a limited scan angle range (15° to 50°, depending on system)
- Projection images acquired (between 9 and 25)
- Focus can be moving or static during the exposure depending on manufacturer
- Detector stationary (patented geometry) or tilted slightly
- Images reconstructed typically to 0.5 mm or 1.0 mm plane spacing
Systems tested

- Siemens and Hologic: moving focus; no grid
- GE: step-and-shoot with a grid
- Other systems available include IMS Giotto and Planmed Nuance
- Philips have a DBT system based on the Microdose (different geometry) – not currently sold
Practical points

- **Time in the room**
  - Between 60 and 180 minutes required to acquire and transfer images
- **Storage requirement**
  - Between ~22 GB and 65 GB of data generated
- **Image availability**
  - Siemens saves projections and planes (as CT sequence) in two separate folders
  - GE saves planes in a single file (files can be up 1,8 GB)
  - Hologic saves planes as a CT sequence – currently no access projections unless you have ‘mview.exe’ from Hologic
- **Image retrieval and analysis** can be time consuming
X-ray generation

- Protocol specifies a 0° stationary mode for x-ray output, tube voltage, HVL and dose measurements
  - Hologic has this mode readily available from menu
  - For GE, go to a command window and use telnet to start 0° stationary mode
  - Siemens does not have 0° stationary mode (yet)

- Siemens can be tested in 2D (planar) mode as W/Rh used for planar and DBT modes (same thickness of Rh filter for DBT and planar mode)
AEC system

• Test uses PMMA and the 0,2 mm Al square (2D planar)
  – Practical but is this an appropriate test object?
• AECs for the three systems are reproducible
• Measurements of SDNR made in projections and the planes (protocol v0,10)
  – Changed to just projection data (v0,14)
AEC system

- GE Essential
  - Similar behaviour DBT projections as for 2D planar
  - Unusual behaviour of SDNR in the DBT planes
  - System has an antiscatter grid and iterative reconstruction
- SDNR no longer calculated from the tomo planes

![Graphs showing relative SDNR vs PMMA thickness for different systems](image)
Image receptor - response

- Detector gain increased in tomo mode
- Typical detector air kerma ~20 µGy (cf 80 µGy for 2D)
Image receptor - response

- Measured from the first projection
  - this is to limit the influence of lag and ghosting
  - GE Essential has ~no lag
Image receptor - noise

- Systems are still quantum limited, despite the low detector exposure, due to the higher detector gain.
Image receptor – sharpness of projections

- Measured with standard edge, placed as fn height above the breast table
- For DBT with moving tube, MTF in projection images is anisotropic due to focus motion
- No sharpness penalty for step-and-shoot systems

Marshall NW and Bosmans H 2012 Measurements of system sharpness for two digital breast tomosynthesis systems Phys Med Biol 57, 7629-7650
Image receptor – sharpness of projections

- Hologic saves binned (2x2) projections – binning unsharpness dominates over tube motion at positions closer to the detector
- Strong differences in sharpness between the systems
Image receptor – uniformity [not in protocol]

- Detector uniformity varies with projection
- Flat field correction is made in the 0° projection only
  - Same behaviour for all three systems
Image quality of the reconstructed image

- Z-resolution
  - Measured with a 1,0 mm Φ Al sphere
  - Can also be measured with thin angled wire

- Test designed to estimate the ability of a system to localize anatomical clutter to a given plane
- Does FWHM capture differences between systems?

<table>
<thead>
<tr>
<th>DBT system</th>
<th>FWHM (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens</td>
<td>4.6</td>
</tr>
<tr>
<td>Hologic</td>
<td>5.4</td>
</tr>
<tr>
<td>GE</td>
<td>4.8</td>
</tr>
</tbody>
</table>
Image quality of the reconstructed image

- Z-resolution
- Protocol specifies a Gaussian fit to the profile – valid?
- Does not characterize the tails in the response
- Gaussian is a symmetric function – but some asymmetry is often seen in measured data

Hologic Dimensions
Image quality of the reconstructed image

- In-plane sharpness
  - MTF measured using 25 µm Φ W wire
  - Wire supported using a 0,5 mm PMMA plate
- Sharpness an-isotropy seen in the projections follows through to planes
Image quality of the reconstructed image

• Example for tube-travel direction
  – MTF in-plane seems to follow MTF in projections

• MTF is important aspect of IQ but not the final word

• Detectability is determined by signal to noise ratio (SNR)
  – Depends on system noise, anatomical noise, sharpness, target (size, shape, position etc)
Image quality of the reconstructed image

- Stability of the reconstructed image
- CDMAM suggested in the protocol
  - Other test objects can be used
- Assesses sharpness and noise in-plane (detail SNR)
- Not final IQ test object
  - Flat test object (position in-plane?)
  - Gold cylinders (wide angle systems)
  - CDCOM ok?
  - No overlying anatomy -> does not test ability of system to suppress overlying anatomical noise
Image quality of the reconstructed image

- Make sure that the plane with lowest threshold gold thickness is assessed
  - This can be time consuming
  - May change if different test equipment (PMMA) is used
- Important to be consistent
  - Image stability test
Image quality of the reconstructed image

- Hologic Selenia Dimensions CDMAM image (plane) is non-uniform
- This will be defeat CDCOM (in fact, CDCOM needs validation)
- A flatfield correction can be applied before scoring with CDCOM
  - The NCCMP (Guildford UK) apply a Butterworth (high pass) filter
  - Not ideal - is this a benign processing step?
- CDCOM uses tag {0018,1164} (Imager Pixel Spacing)
  - CDCOM fails for GE tomo planes
  - The GE DBT system populates tag {0018,7022} (Detector Element Spacing) with pixel spacing for the plane
  - Need to fill tag {0018,7022} with the pixel size and save as DICOM
Dosimetry for DBT systems

• Protocol uses a modified version of the 2D planar formula given by David Dance:

\[ MGD = K g c s T \]

– \( T \) is an average tomo factor, averaged from (‘t’) factors calculated for each projection angle in the scan
– The \( T \) factor depends on the geometry (scan range)

<table>
<thead>
<tr>
<th>PMMA (mm)</th>
<th>tomo factor for -7.5° to 7.5° scan range</th>
<th>tomo factor for -25° to 25° scan range</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.997</td>
<td>0.971</td>
</tr>
<tr>
<td>30</td>
<td>0.996</td>
<td>0.964</td>
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<tr>
<td>40</td>
<td>0.996</td>
<td>0.959</td>
</tr>
<tr>
<td>45</td>
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<td>60</td>
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<tr>
<td>70</td>
<td>0.992</td>
<td>0.952</td>
</tr>
</tbody>
</table>

Dosimetry for DBT systems

- Systems lie below the 2D Acceptable level
- It is not clear that 2D dose limit should directly apply to DBT
  - What is the fundamental source of the 2D Acceptable level? (related to previous technology or a risk calculation etc.)
Dosimetry for DBT systems

- Hologic has dose boost at 50 mm and above
- Siemens has systematically higher dose than 2D planar
- GE have chosen to set same level for DBT and 2D planar (there is a grid for both modes)
Conclusions

- Protocol offers a reasonable performance evaluation of DBT systems
  - Overtesting in early versions of the draft?
- Time consuming to apply, generates large quantities of data, analysis is slow
- Not all systems have modes specified in the protocol (0° stationary tube, available projection images)
- Perhaps the emphasis of the tests should be changed: in depth testing at Acceptance with fewer routine tests?
- There is not yet a 3D image quality test with relevant structures (mass-like; calc-like) in a relevant (anatomical structure) background
Acknowledgement

- Euref team
- LUCMFR, Leuven
- The help of manufacturers for discussion and to get access to the data