Quality control of tomosynthesis imaging systems

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Learning objectives

1. Analyze differences between tomosynthesis and projection radiography
2. Translate these differences into meaningful quality control evaluations

Ground up approach

• We essentially have a radiography system that has been modified to perform tomosynthesis
  – The system can be used for both applications
• Which subsystems are used identically for both modalities?
  – Most of them
• What evaluations are needed and are they sensitive enough?
What are the key differences?

- X-ray source moves to acquire basis images
  - Focal spot blurring
- Detector may move
  - Increased detector blurring
  - Unique artifacts
- Image reconstruction
  - Artifacts
  - Image quality
- Multiple basis images are used for image reconstruction
  - Radiation dose
  - Localization required in the depth direction
  - Geometric calibration

On what timescale do things vary?

- In what phases of the QA process do these aspects need to be addressed?
  - Acceptance
  - Commissioning
  - Acceptability
- Comparison of QC metrics to baseline

Moving X-ray source

- Implication: focal spot blurring
- Evaluation: incorporate both focal spot blurring and receptor blurring in evaluation of tomosynthesis resolution
- Protocol optimization: compare expected blurring in object plane to pixel size and diagnostic task

Note: Place pinhole some distance above recording medium (~ 30-40 cm)
Geometry calibration

- For any system that reconstructs images from a series of projections, the imaging geometry must be known for each projection.
- Calibration can be verified and/or projection-by-projection correction maps generated using phantoms.
Geometry calibration

- Possible impacts
  - In-plane contrast
  - In-plane object localization
  - Depth localization
- In mammographic tomosynthesis, a fixed offset of 1.4° or an interprojection variability (SD) of 0.14° introduces a shift in object localization and contrast, respectively*


Spatial accuracy

- Little discussion of spatial accuracy
  - No mention in the operator’s manual of radiographic systems
    - Is part of tech QC (semi-annual) for one breast tomosynthesis manufacturer
  - More of a potential concern for radiographic tomosynthesis systems?
    - SID calibration
      - Regulatory compliance is not sufficient
      - In fact, image plane accuracy may be the most sensitive SID evaluation we have!
    - Regular evaluation of in-plane contrast, location, and depth location
Artifact spread function

- Proposed by Wu in 2004 to quantify the intensity of out-of-plane artifacts in tomosynthesis
- Plots the out-of-plane signal as a function of distance from the plane in which the object is located

Phantoms

- Littleton phantom
- "Number" phantom
- "Stack" phantom
- Angled wire
- Many other things

Dosimetry

- Dosimetry paradigm:
  - Measure beam quality
  - Measure total EAK
  - Apply CF(op, view, HVL)
- AAPM Report 223 addressed breast tomosynthesis
- Work on body tomosynthesis dosimetry is ongoing

Published recommendations!

- NCRP 99 – the following performance aspects should be monitored
  - Section level
    - ± 5 mm accuracy
  - Level incrcementation
    - ± 2 mm reproducibility
  - Section thickness
    - Limits established by comparing to baseline
  - Exposure angle
    - ± 5° for angles greater than 30°, better for smaller angles
  - Exposure uniformity and pattern
  - Resolution
    - 40 mesh screen pattern resolved
  - Patient exposure
    - Should not vary by more than 20% between identical units
EUREF Tomo Protocol version 1.01

TMIST Daily QC Phantom – middle slice (20 mm)

Artifact seen with TMIST QC phantom (EMI Interference)
Artifact seen with TMIST QC phantom
(EMI Interference)

Works in progress at AAPM

- TG 245: Task Group on Tomosynthesis Quality Control
- TG 223: Task Group on Dosimetry in Tomosynthesis Imaging
  - Report on dosimetry for breast tomosynthesis published
  - Report on dosimetry for body tomosynthesis forthcoming