Quality control of tomosynthesis imaging systems

A. Kyle Jones, Ph.D.
MD Anderson Cancer Center

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?

And their implications…

- 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

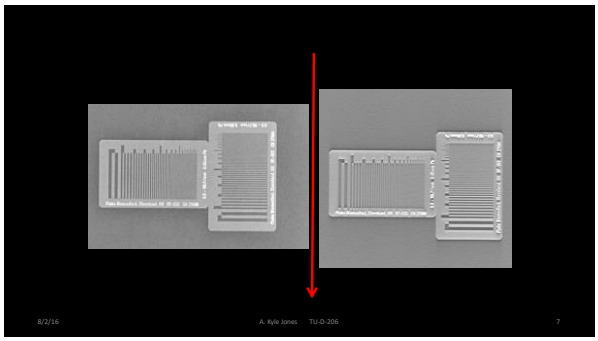
On what timescale do things vary?

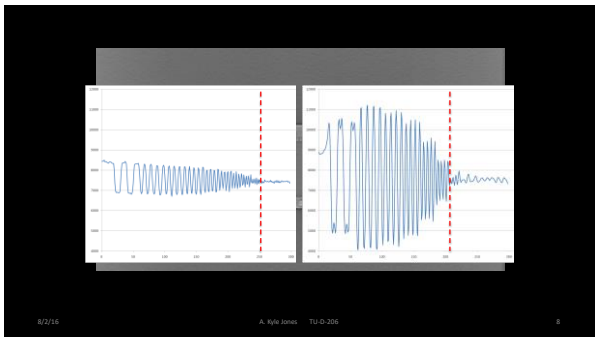
- In what phases of the QA process do these aspects need to be addressed?
  - Acceptance
  - Commissioning
  - Acceptability
- Comparison of QC metrics to baseline

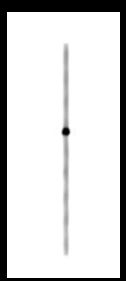
Moving X-ray source

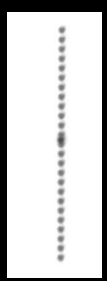
- Implication: focal spot blurring
- Evaluation: incorporate both focal spot blurring and receptor blurring in evaluation of tomosynthesis resolution
- Protocol optimization: compare expected blurring in object plane to pixel size and diagnostic task

Zhao B and Zhao W. Med Phys 35:1978-1987 (2008)

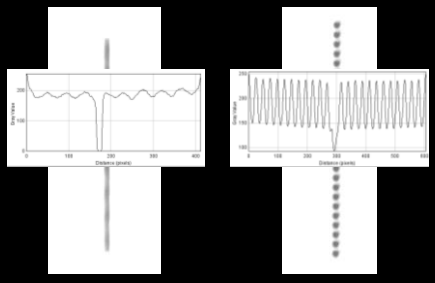


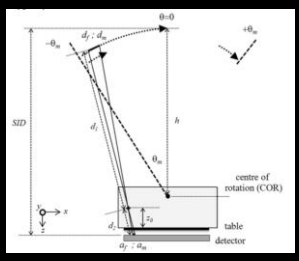






Note: Place pinhole some distance above recording medium (~ 30-40 cm)





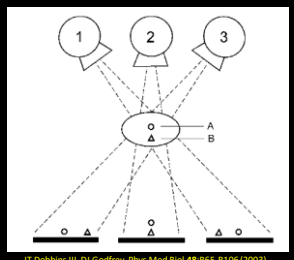
$$d_m = 2h\theta_m \frac{t_{proj}}{t_{scan}}$$

$$a_m = d_m \frac{d_2}{d_1}$$

EUREF Tomo QC Protocol v 1.0.1

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



JT Dobbins III, DJ Godfrey. Phys Med Biol **48**:R65-R106 (2003).

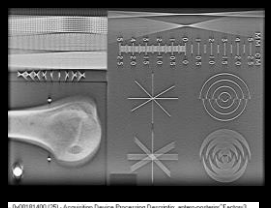
Geometry calibration

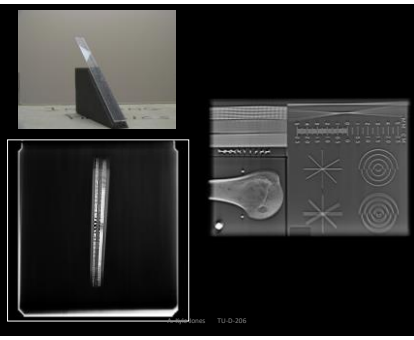
- Possible impacts
  - In-plane contrast
  - In-plane object localization
  - Depth localization
- In mammographic tomosynthesis, a fixed offset of 1.4° or an interprojection variability (SD) of 0.14° introduces a shift in object localization and contrast, respectively*

*Mainprize et al. Med Phys **38**:3090 (2011)

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



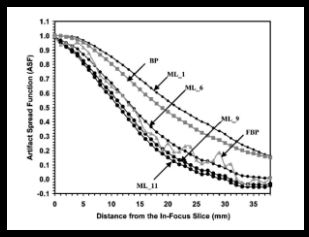


Artifact spread function

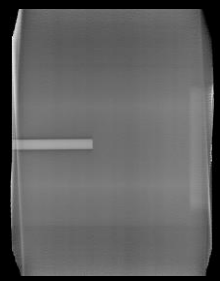
- Proposed by Wu in 2004 to quantify the intensity of out-of-plane artifacts in tomosynthesis
- Plots the out-of-plane signal as a function of distance from the plane in which the object is located

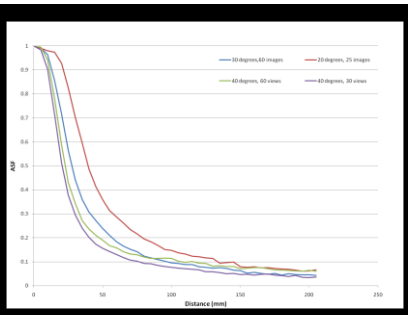
Wu et al. Med Phys **31**:2636-2647 (2004).

$$\mathrm{ASF}(z) = \frac{\overline{\mu}_{\mathrm{Artifact}}(z) - \overline{\mu}_{\mathrm{BG}}(z)}{\mu_{\mathrm{Feature}}(z_0) - \overline{\mu}_{\mathrm{BG}}(z_0)},$$



Wu et al. Med Phys **31**:2636-2647 (2004).

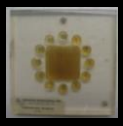




Phantoms

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





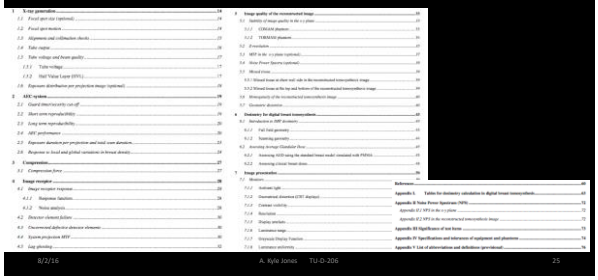
Dosimetry

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

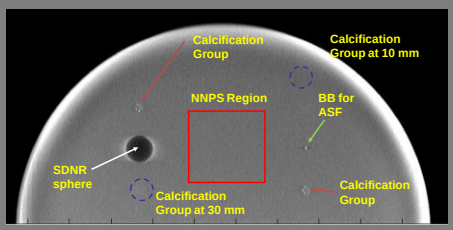
Published recommendations!

- NCRP 99 – the following performance aspects should be monitored
  - Section level
    - ± 5 mm accuracy
  - Level incrementation
    - ± 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)



Aili Maki et al. IWDM 2016

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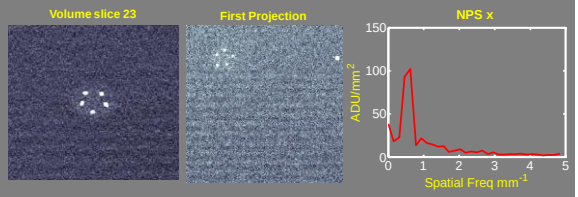
Artifact seen with TMIST QC phantom

(EMI Interference)



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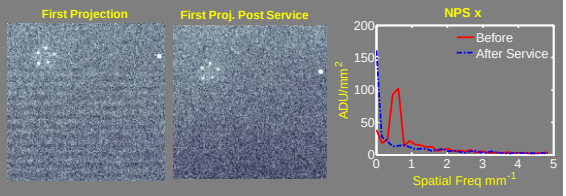

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Works in progress at AAPM

- 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