Features and Weaknesses of Phantoms for CR/DR System Testing

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Physics testing of image detectors

- Parameters to test
  - Spatial resolution
  - Contrast resolution
  - Uniformity/geometric distortion
  - Dose response/signal dynamic range
  - Noise

- Experiments/testing methods
  - Direct measurements
  - Phantoms/image tools
    - Qualitative
    - Quantitative

Phantom Types

- Attenuation
- High Contrast/Spatial Resolution
- Low Contrast/Contrast Sensitivity
- Anthropomorphic

Attenuation test tools

- Metals
  - Aluminum, Copper, etc.

- Plastics/Composite Materials
  - Lucite, Tissue Equivalent, etc.

- Water
Digital detectors can be significantly more sensitive to scatter radiation than traditional phosphor screens. Scatter needs to be considered when testing systems.

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**Attenuator positioning**

- Modifying beam quality
  - Position attenuators far from detector to minimize scatter contribution in measurement

- Simulating patient attenuation
  - Position close to detector in same location as patient

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**Attenuator construction**

- Attenuator "purity" may not be acceptable for the measurement
  - Measurement of mammography HVL requires attenuators that are at least 99.9% Aluminum

- Tissue equivalent materials may not be uniform

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**Attenuation test tools**

- Easy to use

- Placement of attenuator needs to be considered based on the test

- Purity or uniformity of material may not be adequate for some tests
High Contrast/Spatial Resolution Test tools

- Line pair patterns
- Mesh patterns
- Edge phantoms

Aliasing and Moiré Effect

Line pair patterns

Test Pattern

Detector Pitch
Moiré Effect

MTF/DQE Measurement

  - Method for determining Detective Quantum Efficiency (DQE) of digital imaging systems
  - Defines specifications for a test device required to make these measurements

MTF/DQE Measurement Issues

- Requires "For-Processing" image values that are linear with exposure
- Determination of edge response
  - Need to bin pixel data along edge
  - Phantom positioning critical for consistent results
- Smoothing/fitting of edge response curves to allow utilization of Fourier Analysis
  - Variations in method used may produce different results
  - Important to standardize if comparing to other MTF/DQE measurements

MTF/DQE Measurement Issues

- Fluorescent radiation
  - Only issue at high kVp
  - Important if comparing to other MTF/DQE measurements
- Noise Power Spectrum (NPS) determination
  - Need to remove effects of trends associated with heel effect, etc.
  - Variations in method used may produce different results
  - Important to standardize if comparing to other MTF/DQE measurements
MTF Measurements

- Quantitative results
- Good indication of changes
- Subtleties in the measurement can make comparisons between measurements by different tests inaccurate.

High Contrast/Spatial Resolution Test tools

- Line pair patterns
  - Subjective
- Edge Phantoms
  - Objective
  - Requires development of software to do the calculations
  - Task Group No. 162 "Research Software for 2D Images"
  - Valid for determining if changes have occurred over time if performed "consistently"
  - Requires standardization of methods used if comparisons between systems or results from different physicists are compared

Low Contrast/Contrast Sensitivity test tools

- Contains objects of varying size and attenuation
- Requires observers to determine which objects are visible
  - Subjective

Contrast threshold detection index (TCDD)

- TCDD gives an indication of the lowest contrast detectable (C) as a function of the detail size (the square root of the detail Area, A) and can be quoted in terms of the threshold detection index (H)
  \[ H(A) = \frac{1}{C \sqrt{A}} \]
- High value for H(A) indicates good visibility
Institute of Physics and Engineering in Medicine (IPEM)

- Goals:
  - Improving standards in clinical practice
  - Providing advice on scientific and engineering issues in healthcare to other healthcare professionals, government and the public.
  - Developing reports and other publications to achieve these goals
  - Owns several journals:
    - Physics in Medicine and Biology
    - Physiological Measurement
    - Medical Engineering and Physics
  - Report 91 Recommended Standards for the Routine Performance Testing of Diagnostic X-Ray Imaging Systems
    - Specifies the use of phantoms throughout the testing procedures

IPEM Criteria (example)

- Most results are subjective!

ACR Radiography/Fluoroscopy Accreditation Phantom

- Modules included
  - Chest
  - General
  - Fluoroscopy
- Phantom image
  - Radiography Chest/Abdomen
- ACR Discontinued Radiography/Fluoroscopy Accreditation Program in 2005

Original Equipment Manufacturer (OEM) Products

- Automated Image Quality Control Tool
  - Reproducible quantitative results
  - May detect sub-visible changes in image quality performance to initiate timely preventive maintenance
  - Highly automated procedure
  - Most provide data reporting in spreadsheet format
Test Phantom for Kodak (i.e. CareStream)
DIRECTVIEW Total Quality Tool

*Images provided by Eastman Kodak Company

Tests
- Uniformity
- Noise
- Spatial frequency response (MTF)
- Exposure linearity
- Pixel size accuracy and aspect ratio
- Phantom image artifacts
- Laser Beam Function
- Residual signal erase

Test Results

Temporal Test Results
Test Limits

- Pre-set by OEM
- Basis for limit may not be justified in OEM literature
- If system fails a test, Service Engineer may not be educated how to correct problem


- Acceptance testing and constancy checks of projection radiography systems with digital image receptors
  - German standard for testing of Storage Phosphor systems using a specially designed phantom to measure image quality parameters
  - Can purchase a phantom that will meet the requirements of this standard from several vendors
  - TG151 Digital Radiography QA is investigating this type of test tool for a "generic" phantom

Anthropomorphic phantoms

- Shape "mimicking"
- Anatomically Accurate
Shape "mimicking"

Anatomically Accurate

To optimize image processing parameters the phantom would need to accurately mimic "true" anatomy.

At least one reference of a study attempting to accomplish this with a phantom for a specific vendor processing method*

It is acknowledged that at present it is not possible to get unprocessed images from some systems. The image processing may introduce artifacts on phantom images and may be different from image processing for mammograms due to histogram or local texture based processing techniques. Therefore care needs to be taken in interpretation of these processed images.

AAPM Report 93: Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems

- Recommends using vendor/manufacturer supplied phantom for Quality Control testing
  - Since each vendor/manufacturer system would be different, the Report cannot specify exactly what to do or look for in the results

- Also lists anthropomorphic phantoms in the recommended equipment list
  - Doesn't specify how to use the anthropomorphic phantoms in the Report