Digital and Computed Radiography: Acceptance Testing and Quality Control

Napapong Pongnapang, Ph.D.
Department of Radiological Technology
Faculty of Medical Technology
Mahidol University
Bangkok, Thailand
Content

- Digital Radiography
  - Photostimulable Phosphor (CR)
  - Flat Panel Detectors (DR)
- Acceptance Testing Guidelines
- Setting up a Quality Control Program
Computed Radiography
Photostimulable Luminescence
X-Rays Flat Panel Detector
Flat Panel Detectors

- Direct DR (DDR): Amorphous Selenium Detector – matrix of transistors, without photon conversion layer
- Indirect DR (IDR): Amorphous Silicon TFT or CCD with CsI conversion layer
Flat Panel Detector Configurations

Indirect DR

Direct DR
Acceptance Testing - Purpose

- To ensure the machine acquired meets detail specifications under the commercial contract
- To ensure clinical quality of the machine for optimal patient safety and image quality
- To set up baseline values for Quality Control (QC) purpose
Acceptance Testing - Process

• Get list of equipment package (inventory)
• Check standard acceptance testing procedures specific to each equipment
  – American Association of Physicist in Medicine (AAPM)
  – Institute of Physics and Engineering in Medicine (IPEM)
  – Others Organizations provide standards (IAEA – soon)
• Get Test Tools
  – Phantoms
  – Dosimeter
  – Other measurement equipments
Acceptance Testing - Components

- X-Ray Tube
  - kVp, Timer
  - Tube Leakage
  - HVL, Linearity, reproducibility
- CR Plate/Scanner
- Detectors
- Patient Dose
Acceptance Testing: X-Ray Machine

- Use similar methods for general x-ray machines

Concerned Points
- Don’t direct expose the detector with high dose!
- Use Lead apron to block the detector
Acceptance Testing – CR Protocols

AAPM REPORT NO. 93

Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems

Report of AAPM Task Group 10
October 2006
Acceptance Testing (AAPM)

Phosphor Plate Dark Noise
System Linearity, Auto-Ranging and Exposure Response
Receptor Reproducibility, Density Uniformity & Artifact Analysis
Phosphor Plate/Cassette Throughput
Laser Beam Function
Spatial Resolution
Wire Mesh Test - Resolution Uniformity Across Receptor
Low Contrast Sensitivity/ Detectability
Distance Accuracy Measurements and Aspect Ratio Test
Accuracy/Thoroughness of Erasure Cycle
CR Acceptance Test/QC Consideration

- Image Acquisition
- Electro-mechanical readout
- Image processing
- PACS/RIS interface
- Image handling
Recommended Acceptance Tests

- Physical inspection/inventory/PACS interface
- Image plate uniformity and dark noise
- Signal response: Linearity and Slope
- Signal response: Exposure calibration and beam quality
- Laser beam function
- High contrast resolution
Recommended Acceptance Tests

- Noise-Low contrast response
- Distortion
- Erasure thoroughness
- Artifacts analysis
- Positioning and collimation robustness
- Image plate throughput
Acceptance Test Tools Required

- Exposure / dose meters
- Spatial resolution phantom
- Low contrast phantom
- SMPTE pattern
- Anthropomorphic phantom
- Document log/spreadsheet/instructions
Phosphor plate dark noise

- The resultant film (or soft-copy image) for each plate should demonstrate a clear, uniform, artifact-free image.
- Exposure indicators for automatic processing should indicate no incident exposure.
- Obvious artifacts, density shading, or uniformities present on any output image should be evaluated further.
System Linearity, Auto-ranging and Exposure Response

- Make sure linearity response of CR system
- Test by calibrating 1 mR exposure at specific vendor condition
- Fuji use S = 200 Semi-Auto mode exposed at 80 kVp @ specified distance
- Other vendors; refer to TG10
“S” Number - Sensitivity

It reflects the center of the usable portion of the histogram

Calibration is based on a 1 mR exposure at 80 kVp to the IP. Using a 72” distance through air to achieve an “S” number of 200 with a fixed latitude of 1.
Receptor Reproducibility, Density Uniformity & Artifact Analysis

- Make sure uniform image intensity across irradiated field
- At same exposure and image processing condition, same uniformity is expected
- No artifacts should be detected.
Uniformity
Phosphor Plate/Cassette Throughput

- Make sure throughput meets with vendor’s specifications
- Fuji FCR 5000+ = 109 plates/hr
Spatial Resolution

- Make sure spatial resolution meets specification provided by vendors
- This test requires same test conditions specified by vendors
- There are many factors affecting resolution
CR: Spatial Resolution

- Phosphor plate sizes: impact on resolution

35x43 (14x17)  24x30 (10x12)  18x24 (8x10)

0.2 mm pixels  0.14 mm pixels  0.1 mm pixels
High Contrast (Spatial) Resolution

18 x 24 cm

35 x 43 cm
Wire Mesh Test - Resolution Uniformity Across Receptor

- Similar to screen-film contact test done in conventional radiography
- To make sure uniformity across receptor
Wire Mesh Test - Resolution Uniformity Across Receptor
Low Contrast Sensitivity/ Detectability

- To test low contrast sensitivity of CR to different levels of radiation dose
- To see effects of SNR levels
Low Contrast – UAB Phantom

Low contrast at 5 mR
2.9%

Low contrast at 1 mR
3.28%
Distance Accuracy Measurements and Aspect Ratio Test

- To test accuracy of distance measurement
- Test by imaging a known size object
Distance Accuracy Measurements and Aspect Ratio Test
Accuracy/Thoroughness of Erasure Cycle

- Make sure that erasure cycle functions well
- Need very high radiation exposure and dense material
Accuracy/Thoroughness of Erasure Cycle

BEFORE

AFTER
Acceptance Testing – DR Protocols

- Currently, no published dedicated protocol available
- IPEM No.91 describes extended methods to test Flat panel on top of general x-ray equipment testing
- AAPM is likely to release TG 151 in 1-2 years
DR Test Protocols

• What are now available?
  – IPEM
  – AAPM TG 116 – for Exposure Index Standards
  – AAPM TG 18 – for Display Devices
  – Vendor Specific Test Protocols
    • GE
    • Siemens
    • Philips
    • Cannon
    • Others
Review: Available International/National Standards

- Deutsches Institut Fur Normung, Germany

- The Institute of Physics and Engineering in Medicine, UK
  - IPEM Report #91 (2005)

- KCARE, UK
  - Provides details on how to do acceptance testing for DR
What are recommended?

- DIN 6868-58
  - Dynamic Range
  - Limited Spatial resolution
  - Low Contrast
  - Homogeneity
  - Artifacts

- KCARE DR
  - Dosimetry
  - Dark Noise
  - Detector dose indicator consistency
  - Uniformity
  - Blurring and stitching artefacts
  - Limiting spatial resolution
  - Threshold Contrast at different dose levels

- IPEM
  - Detector dose indicator monitoring
  - Image uniformity
  - Low contrast sensitivity
  - Limiting spatial resolution
  - Detector dose indicator reproducibility
  - Measured uniformity
  - Uniformity of resolution
  - Threshold contrast detail detectability
  - Scaling error
  - Dark noise
Detector dose indicator monitoring

- IPEM refers the method to the British Institute of Radiology
- Basically, you check if the Detector Dose Indicator corresponds to the dose exposed to the detector
- AAPM TG 116 provides details on Exposure Index for different vendors
# Exposure Index

## The El “Currencies”

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Name</th>
<th>Symbol</th>
<th>Range (typ.)</th>
<th>Value @ 2.5 μGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agfa (CR)</td>
<td>Logarithmic median</td>
<td>LgM</td>
<td>1.6 – 2.2</td>
<td>Depends on selected speed</td>
</tr>
<tr>
<td>Canon (DR)</td>
<td>Reached Exposure</td>
<td>REX</td>
<td>?</td>
<td>Depends on processing</td>
</tr>
<tr>
<td>Fuji (CR)</td>
<td>Sensitivity</td>
<td>S</td>
<td>200 – 800</td>
<td>200</td>
</tr>
<tr>
<td>Kodak (CR)</td>
<td>Exposure Index</td>
<td>EI</td>
<td>1300 – 1800</td>
<td>1500</td>
</tr>
<tr>
<td>Philips (DR)</td>
<td>Exposure Index</td>
<td>EI</td>
<td>200 – 800</td>
<td>400</td>
</tr>
<tr>
<td>Siemens (DR)</td>
<td>Exposure Index</td>
<td>EXI</td>
<td>200 – 800</td>
<td>380(?)</td>
</tr>
</tbody>
</table>
Exposure Index Scales

<table>
<thead>
<tr>
<th>Exposure Level</th>
<th>Philips EI</th>
<th>Fuji S</th>
<th>Siemens EXI</th>
<th>Kodak El</th>
<th>Agfa IgM</th>
<th>Agfa IgM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25 μGy</td>
<td>800</td>
<td>1600</td>
<td>190</td>
<td>1100</td>
<td>1.3</td>
<td>1.6</td>
</tr>
<tr>
<td>2.5 μGy</td>
<td>400</td>
<td>800</td>
<td>380</td>
<td>1400</td>
<td>1.6</td>
<td>1.9</td>
</tr>
<tr>
<td>5 μGy</td>
<td>200</td>
<td>400</td>
<td>760</td>
<td>1700</td>
<td>1.9</td>
<td>2.2</td>
</tr>
<tr>
<td>10 μGy</td>
<td>100</td>
<td>200</td>
<td>1520</td>
<td>2000</td>
<td>2.2</td>
<td>2.5</td>
</tr>
</tbody>
</table>

SC = 2205 SC = 400

www.philips.com
Image Uniformity

- Expose blank detector to see any lines or rectangular areas
- If any seen, detector needs to be recalibrated
Low contrast sensitivity

- Test contrast level at different dose to detector
- Needs test objects such as Leeds TOR and Cu attenuator (or equivalent)
- Establish baseline for future comparison
Low Contrast Response: Leeds TO-16

3.5 mR  70 kVp  0.5 mR
Low Contrast – UAB Phantom

Low contrast at 5 mR
2.9%

Low contrast at 1 mR
3.28%
Limiting Spatial Resolution

- Lead grating resolution bar pattern is recommended
- Use low tube voltage about 50 kVp without filtration
- Angle the test pattern at 45 degree
- Establish baseline for future comparison
Line pairs test pattern

Shown in Model 07-501-2000

Shown in Model 07-523-1000/2000

Shown in Model 07-527

Shown in Model 07-541-2000
Detector dose indicator repeatability

- Expose the detector with same dose for 3 times
- Record the Exposure Index
- 70 kVp with 1.0 mm Cu attenuator is recommended for dose of 10 uGy
Detector dose indicator reproducibility

- Similar to previous test but do at different dose levels
- Can be used as monitoring tool for long term decline of the system
Measured Uniformity

- Use image from previous test
- Draw 5 ROIs about 100x100 pixels
- Calculate SD from five ROIs divide by the mean value
Uniformity
Uniformity of resolution

- Use fine wire mesh
- Expose at low tube potential at 50 kVp, SID = 1 meter
- No filtration added
- Check for blurred areas
Scaling Error

- Use highly attenuated objects such as ruler or test pattern with grids of known distance
- Check for accuracy of distance measurement
- Repeat with film, if laser printer is used.
Dark Noise

- Obtain image with no or very low exposure
- Purpose is to check electronic noise
- Can also expose the detector using highly radiation attenuated block
Setting up a QC Program for DR
Quality Control

- Modern equipments have good maintenance program, why need QC?
- QC = maintain standard
  - For image quality, dose and safety
- Results of QC can be used to dictate level of action
  - For further tests needed, call engineer, stop scanning
  - Reassurance of ongoing quality, solving clinical image problems, provide evidence to manufacturer
How do we get start?

- Medical physicist performs acceptance testing
- Medical physicist sets up QC activities run by QC Technologist/Physicist
### IPEM Recommendation:
Routine Testing for DR

<table>
<thead>
<tr>
<th>Physical Parameters</th>
<th>Level of Expertise</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector dose indicator monitoring</td>
<td>A</td>
<td>1-3 monthly</td>
</tr>
<tr>
<td>Image uniformity</td>
<td>A</td>
<td>1-3 monthly</td>
</tr>
<tr>
<td>Low contrast sensitivity</td>
<td>A</td>
<td>4-6 monthly</td>
</tr>
<tr>
<td>Limiting spatial resolution</td>
<td>A</td>
<td>4-6 monthly</td>
</tr>
<tr>
<td>Detector dose indicator repeatability</td>
<td>B</td>
<td>12 monthly</td>
</tr>
<tr>
<td>Detector dose indicator reproducibility</td>
<td>B</td>
<td>12 monthly</td>
</tr>
<tr>
<td>Measured uniformity</td>
<td>B</td>
<td>12 monthly</td>
</tr>
<tr>
<td>Threshold contrast detail detectability</td>
<td>B</td>
<td>12 monthly</td>
</tr>
<tr>
<td>Limiting spatial resolution</td>
<td>B</td>
<td>12 monthly</td>
</tr>
<tr>
<td>Uniformity of resolution</td>
<td>B</td>
<td>12 monthly</td>
</tr>
<tr>
<td>Scaling errors</td>
<td>B</td>
<td>12 monthly</td>
</tr>
<tr>
<td>Dark noise</td>
<td>B</td>
<td>12 monthly</td>
</tr>
</tbody>
</table>
What is needed?

- Computer friendly phantom
- Objective quantitative analysis method
- System performance tracking and database logs
- Exposure monitoring tools and database tracking
CR/DR QC Phantom

CR/DR EZ - Daily QC Phantom
One shot image quality evaluation
CR/DR QC Phantom

ACR R/F Accreditation Phantom
Daily QC

MEDICAL PHYSICS AND RADIATION SAFETY UNIT, PHYATHAI HOSPITAL

Digital Radiography Quality Control by QC Technologist

Month: ....................... Hospital: ......................

X-Ray Room/Portable machine# .................. Technique: kVp ............... mAs ..................

<table>
<thead>
<tr>
<th>Date</th>
<th>X-Ray unit ok?</th>
<th>Console ok?</th>
<th>PACS connection ok?</th>
<th>Secondary Erasure (CR)</th>
<th>Phantom Image</th>
<th>QC Tech Initial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Resolution</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Contrast</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Artifacts</td>
<td></td>
</tr>
</tbody>
</table>

1
2
3
4
5
6
7
8
9
10

Verified by ..................................................

Dr. Napapon Pongnapang/ Medical Physicist
Hard copy/Display QC
SMPTE/TG-18 Test Pattern
Laser Film QC

Weekly:

View SMPTE pattern
Verify gray levels
- 0/5% & 95/100% patches

Film 6 on 1
- 4 on 1 if necessary

Plot OD of
- 10%, 40% & 90% patches

Observe film for artifacts

SMPTE Test Pattern
## Action Limits

<table>
<thead>
<tr>
<th>SMPTE patch</th>
<th>OD</th>
<th>Control Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.45</td>
<td>±0.15</td>
</tr>
<tr>
<td>10%</td>
<td>2.10</td>
<td>±0.15</td>
</tr>
<tr>
<td>40%</td>
<td>1.15</td>
<td>±0.15</td>
</tr>
<tr>
<td>90%</td>
<td>0.30</td>
<td>±0.08</td>
</tr>
</tbody>
</table>
Conclusion

- Digital Radiography includes PSP, IDR and DDR
- Acceptance Testing and QC for each type of the technology are different
- Numbers of standard test protocols are available but not harmonized
- Acceptance test procedures and set up QC program must be done to ensure the quality of the radiological services provided