Quality Assurance In Diagnostic Radiology

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Why Do Quality Control?

- Improve clinical results
- Preempt quality or safety problems
- Maintain standard of care
- Minimize patient radiation dose
- Satisfy government regulations
QC Testing

• Acceptance testing
  – Upon installation prior to patient use
  – Medical physicist
• Annual inspection
  – Medical physicist
  – Equipment vendor/service provider
• Daily and weekly tests
  – QC technologist

Quality Control (QC)

• Team approach
  – Radiologists, Medical Physicists, Technologists
• Use eyes and experience
• Don’t “work around” problems
• Try to be preemptive
**Mechanical Integrity**

- Fix problems as soon as possible
  - They only get worse
- If things become loose, tighten them!

**Regulations**

- Are more better?
- Are all of equal value?
- Do they cover all aspects of IQ and safety?
  - Should I stop when all the regulatory tests are complete?
Quality Control

- Emphasize those tests that are important to IQ and/or safety
  - Concentrate on those functions that effect quality and safety
  - Minimize time on activities done primarily to meet regulations

Digital Projection Imaging: QC

X-ray tube
Collimator
X-rays
Patient
Grid
Detector
X-Ray Tube Concerns

- Focal spot size
  - Component in spatial resolution
- Worn anode
  - Variation in intensity across field
  - Increase in HVL due to metal coating on inside of glass
- Instabilities, arching

Focal Spot Measurement

- When?
  - Acceptance
  - Annually
  - Tube replacement
- How?
  - Star pattern-measure spatial resolution
  - Pinhole camera
Spatial Resolution Measurement

- Image a lead bar test pattern
- Assess using vendor QC software to determine contrast of specific line pairs
  - MTF can be obtained
- Determine along both axis or at an angle of 45°

Pinhole Camera

- The best
  - Shows emission distribution
  - Difficult and time consuming
  - Not possible for some tubes
- Use CR and large magnification factor (≥ 5x)
- Careful alignment

\[ F = S \left( \frac{L_1}{L_2} \right) = S \left[ \frac{1}{(M-1)} \right] \]
**Generator QC**

- **Consistent x-ray output for same technical factors (KVp, mA, exposure time)**
- **mA and time settings**
  - *Should be linear*
  - *Should be consistent*
  - *mR/mAs should be a constant*
- **KVp calibration**

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**Collimators**

- Restrict primary X-ray beam to detector size or a smaller anatomic region-of-interest
  - Restriction and alignment of X-ray beam to detector
- Major component in radiation protection
  - Reduces scatter
    - Lower personnel exposure
    - Improved image quality
  - Reduction in patient radiation burden
- Component in beam filtration
Collimator

• What?
  – X-ray field - detector alignment
  – X-ray - light field alignment

• When?
  – Acceptance
  – Annually
  – Tube replacement

X-ray - Light Field Alignment

• Sum on opposite sides $\leq 2\%$ of the source-image distance (SID)
**Filtration**

- Minimum amount set by regulation
- Determined by measuring the HVL
  - Thickness required to reduce X-ray intensity to half its initial value
  - Measured in mm of Al
  - Measure of X-ray beam penetrance (hardness)

**Filtration/Beam Quality**

- Indicated by measuring half value layer (HVL)
- Need to measure at only a single KVP
  - Tube potential indication should be calibrated

<table>
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<th>Tube Potential, KVP</th>
<th>Minimum HVL, Mm Al</th>
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<tr>
<td>50</td>
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<tr>
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<td>2.7</td>
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Filtration

- Current digital R/F and angio systems have variable filtration
  - Combinations of Al and Cu of various thicknesses
  - Anatomic protocols automatically change
- Measure HVL at minimum filtration

Basic Imaging Geometry: Detector

- Converts X-ray intensity to electrical signal
- Major component of spatial resolution
- Major determinate of patient dose
- Component of automatic exposure control system
Digital Detectors: Radiography

• What?
  – Uniformity
  – Artifacts
  – AEC

• When?
  – Acceptance
  – Annually
  – Component replacement
  – Manufacturers recommendation

Digital Detectors: Flat Field Uniformity

• Digital detectors do not respond uniformly across field
  – Produces density variations within the image
  – ‘Structured’ noise

• Assessed by uniformity of pixel values (eg. Mean and standard deviation)

• Most systems have software that automates testing
Digital Detector Structured Noise

- Periodically generate new correction matrix
  - Follow manufacturers recommendation
  - Often done by technologist

Digital Detectors: Artifacts

- Non-uniformities
- Dropouts and dead pixels
- Determined by imaging uniform plastic block
  - View with narrow W/L
**Automatic Exposure Control (AEC)**

- Should be able to maintain a pixel mean value within ~15%
  - Track with changes in KVP
    - Clinically used range (~ 50 - 120 KVP)
  - Track with changes in patient thickness
    - 5 - 35 cm of water equivalent

**Annual Testing - Key Measurements**

- Mechanical integrity
- Linearity of mAs
- Half value layer
- X-ray field - detector size
- Light - x-ray field alignment
- Spatial resolution
- Artifacts/uniformity
- AEC consistency
Fluoroscopy QC

• What?
  – Table-top exposure rate
  – Automatic brightness control

• When?
  – Installation
  – Annually
  – Major component changes
  – Manufacturer’s recommendation

Typical Regulations
Fluoroscopic Equipment

• Table-top exposure rate cannot exceed 10 R/min

• During routine fluoroscopy the table-top (patient entrance) exposure rate shall not exceed 5 R/min for a typical patient
  • Determined by use of a phantom equivalent to 8” of water
**Automatic Exposure Control (AEC)**

- Feedback mechanism that attempts to maintain a constant brightness level from the center portion of the output screen
  - center weighted exposure meter
  - adjusts the X-ray technique factors (mA and/or KV)
- Determinate in patient dose

![Feedback loop diagram]

**Automatic Exposure Control**

- For a given object size, should require same kVp and mA
- California:
  - 8 inch plastic (lucite) phantom
  - 12 inch table-top to entrance surface distance
  - 6.25 x 6.25 inch field at table-top
  - Record kVp and mA weekly
**Fluoroscopy - Image Quality**

- **Image resolution pattern**
  - Bar pattern (line pairs/mm)
- **Contrast sensitivity**
  - Low contrast phantom

Problem: very subjective

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**Computed Tomography QC**

- **What?**
  - Dose
  - Slice thickness/sensitivity profile
  - Table incrementation accuracy
  - Image quality factors
- **When?**
  - Installation
  - Annually
  - Major component changes
  - Manufacturer’s recommendation
Image Quality CT

• Uniformity
• Artifacts
• Linearity
• Noise
• Spatial resolution
• Contrast sensitivity

CT Dose Measurements

• CTDI
• In air at isocenter (mR/mAs)

AAPM phantom

CT Dose Measurements

• CTDI
• In air at isocenter (mR/mAs)
QC Challenges

• Man-machine interfaces
  – What goes on in the software black box?
  – How to test?

Cedars-Sinai CT Overexposures

• What happened?
• Brain perfusion procedures
  – Used in stroke assessment
• Over-rode ‘default’ protocol settings
  – Protocols come with the machine
  – Changed technique factors that effect dose
• Eight times the protocol dose
Cedars-Sinai CT Overexposure

• Went on for 18 months because no one made the association of hair loss and skin reddening with CT procedure
  – 2-3 weeks after exposure before onset of hair loss

Cedars-Sinai CT Overexposure

• Errors at multiple levels
  – Originally caused by changing default protocol
  – Dose indicators appear at time of scan: should have been recognized at time of scan
  – Radiologist should have realized overdose from the images

• Not found during any QC testing
Conclusions

• QC is a necessary and valuable aspect of x-ray imaging
• QC should be a meaningful endeavor not just going through the motions
  – React to problems before they interfere with patient images
• Not all QC tasks are of equal value
  – Concentrate on the important ones (those that effect patient safety and image quality)