Quality Assurance In Diagnostic Radiology

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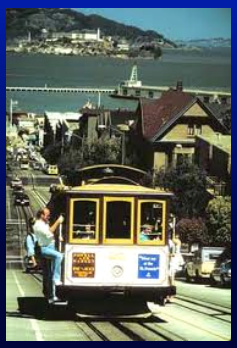


Why Do Quality Control?

- *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!*

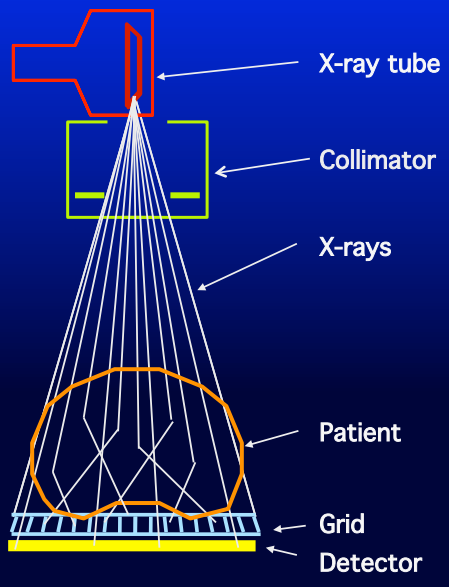
Regulations

- *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 Concerns

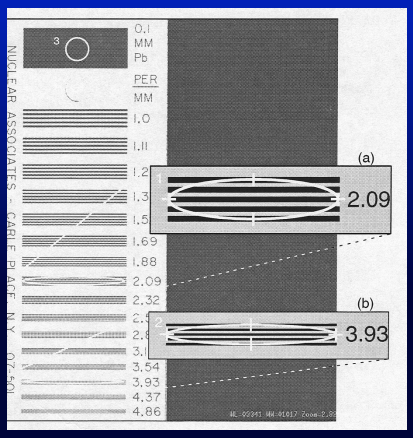
- Focal spot size
  - Component in spatial resolution
- Worn anode
  - Variation in intensity across field
  - Increase in HVL due to metal coating on inside of glass
- Instabilities, arching

Focal Spot Measurement

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

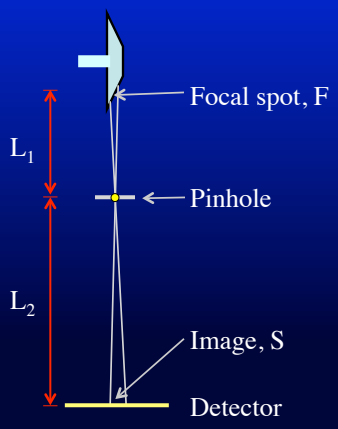
Spatial Resolution Measurement

- *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*



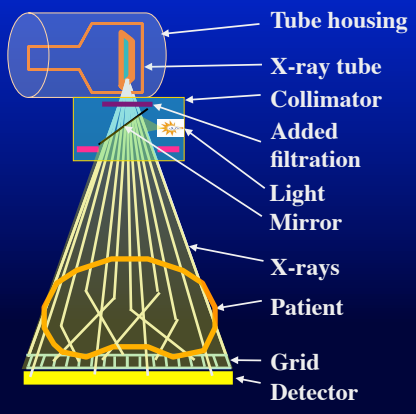
$$F = S\,(L_1/L_2) = S\,[1/(M-1)]$$

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*

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

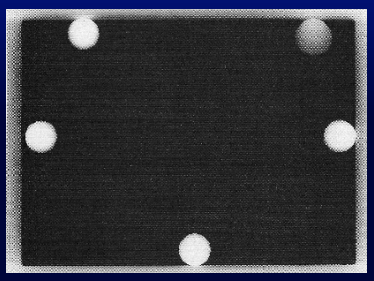


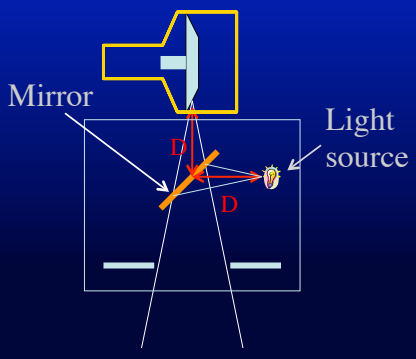
Collimator

- What?
  - X-ray field - detector alignment
  - X-ray - light field alignment
- When?
  - Acceptance
  - Annually
  - Tube replacement

X-ray - Light Field Alignment

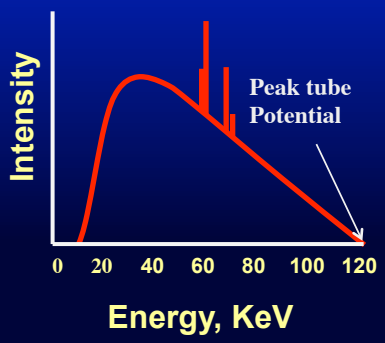
- Sum on opposite sides $\leq$ 2% of the source-image distance (SID)





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*

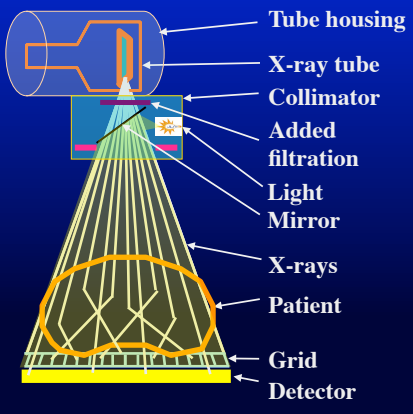
Tube Potential, KVp	Minimum HVL, Mm Al
50	1.5
71	2.1
80	2.3
100	2.7
120	3.2

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

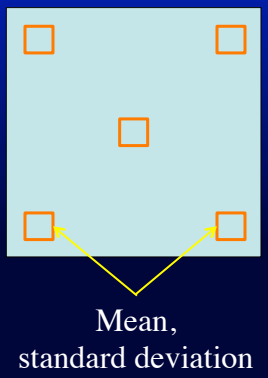


Digital Detectors: Radiography

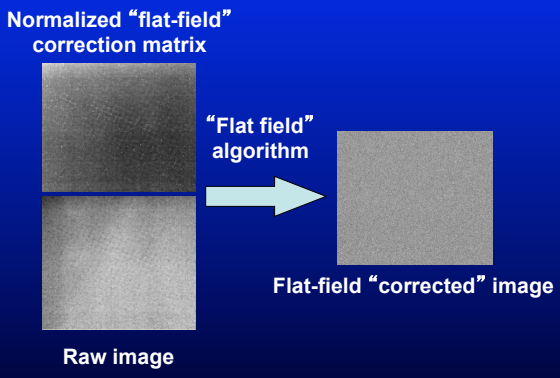
- What?
  - Uniformity
  - Artifacts
  - AEC
- When?
  - Acceptance
  - Annually
  - Component replacement
  - Manufacturers recomendation

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

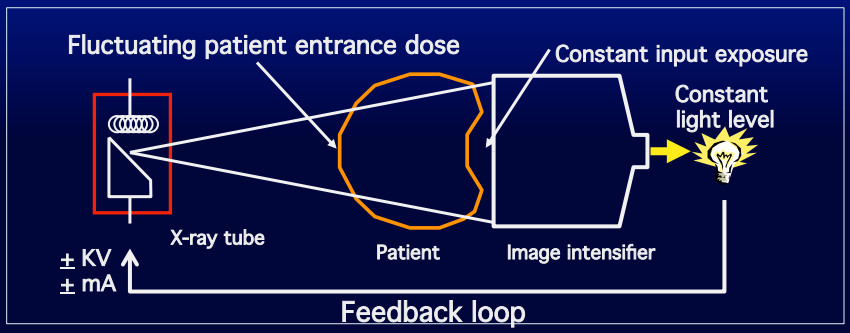
- What?
  - Table-top exposure rate
  - Automatic brightness control
- When?
  - Installation
  - Annually
  - Major component changes
  - Manufacturer's recommendation

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 ExposureControl (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*



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

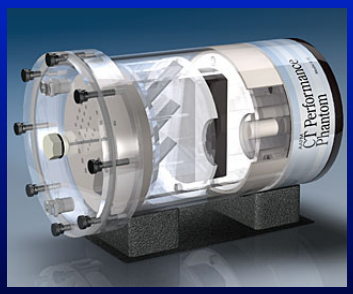
Problem: very subjective

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



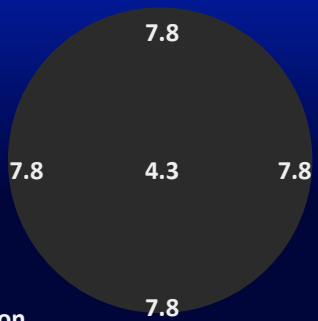
AAPM phantom

CT Dose Measurements

- CTDI
- In air at isocenter (mR/mAs)

Cylindrical PMMA

120 KVp
100 mAs
360˚ rotation
64 slice CT



Body
32 cm diameter

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)*