Radiographic Quality

OR: "MAKING PRETTY PICTURES"

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• 10 February 2011

What is a Good Radiograph?

• You can see everything that you’re supposed to in a given study
• Depends on the intent of the study
  – Thoracic spine?
  – Heart and lungs?
• Patient positioning important, but we’ll leave that for later discussions

Artifacts

• Component of image
  – Not real structure AND/OR
  – Interferes with image interpretation
• Can occur anywhere in the imaging process
  – From the production of electrons to the storing of an image file or anything in between
• We’ll mostly talk about these in lab and in a couple of lectures

Perception

• Be aware of optical illusions
• Mach lines
  – Appear at interfaces of different opacities
  – Can be mistaken for fractures

Reference to Consider


The Grand Plan

• Image Geometry
• Film Density
• Radiographic Contrast
• Image Detail
• Exposure Technique
• Quirks of Digital Radiography
Radiographic Quality

- Image Geometry
- Film Density
- Radiographic Contrast
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Basic Points

- Divergent Beam – Photons travel in all directions from the source (focal spot)
- The source has dimensions – not just a point in space
- Photons travel in straight lines
  - Scatter radiation confounds this postulate, which is why scatter is troublesome
- Image is 2D representation of 3D object

Cathode

Larger penumbra = more unsharpness

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Inverse Square Law

- Intensity of X-ray beam
  - Directly proportional to mAs
  - Inversely proportional to square of distance
- Due to divergence of X-ray beam
- If distance doubles, must increase mAs 4x to maintain optical density

\[
\frac{I_1}{I_2} = \left(\frac{d_2}{d_1}\right)^2
\]

Relative Intensity

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\[ \text{relative } I_2 = \left( \frac{d_1}{d_2} \right)^2 \]

Relative \( I_2 = \left( \frac{40}{80} \right)^2 \)

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Relative \( I_2 = \left( \frac{1}{2} \right)^2 \)

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Relative \( I_2 = \frac{1}{4} \)

Heel Effect

- Uneven X-ray beam intensity within field
- Less intensity on anode side of field
  - Some X-rays traveling in that direction are actually absorbed by the target itself
- Position the thick end of the patient toward the cathode

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Magnification

- Enlargement of the image relative to the actual size of the object
- Size on image determined by:
  - Object size
  - Subject-film distance
  - Tube-film distance

Magnification

- Magnification is BAD
  - Exaggerates size
  - Increases unsharpness (penumbra)
  - Distorts image
- Minimize magnification:
  - Minimize SFD
  - Maximize TFD

Subject-Film Distance

Tube-Film Distance
Magnification & Penumbra

Distortion / Foreshortening

- Misrepresentation of object's shape and position
- Caused by unequal magnification of parts of object

Distortion

Don't Forget …

Silhouette Effect

Summation Sign
Radiographic Quality
- Image Geometry
- Film Density
- Radiographic Contrast
- Image Detail
- Exposure Technique
- Quirks of Digital Radiography

Optical Density
- Evaluate entire image
  - High optical density = black
  - Low optical density = white
- Directly related to how many photons interacted with film

Things Affecting Optical Density
- *** mAs *** – direct and linear
- *** kVp *** – direct but not linear
- Film/screen system
- Processing
- Grid (if technique not modified)
- Proper technique chart is critical
  - More about this in Lab

Optical Density – Too White
- Film periphery (away from the patient) should be BLACK
  - If you can see your finger through the film, it's not black enough
- If periphery not black enough, cause is:
  - mAs too low (underexposure)
  - Inadequate development (underdevelopment)

Optical Density – Not Too White
Optical Density – Too White

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Optical Density – Too White

Increase mAs

Inadequate Exposure

• mAs too low
  – Double it
  – Did you put a grid in?
  – Is the tube-film distance too long?
    • Inverse square law
  – Using slower (detail) screen/film combo?
• Obstruction to photons
  – Paper in cassette, 2 films in cassette
• Tube voltage not constant
  – Can be issue with portable units
• Tube problem – call the service guy person

Inadequate Developing

• Developer diluted or mixed incorrectly
  – Replenish developer
  – Replace developer
• Development time too short
• Developer temperature too cold

Poorly exposed or Poorly developed?

• Check the radiographic label
  – This gets “flashed” with light photons
  – Is not part of the initial exposure
• Looks good?
  – Exposure issue
• Also bad?
  – Development issue

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Optical Density – Too White
- If periphery is black but the anatomy is too white, check the overall detail
- Can’t see anything
  - Increase kVp – need more penetration
- Can see some detail
  - Increase kVp or mAs

Corrected Image

Optical Density – Too Black
- Evaluate small thin bones using a hot light
- Bones visible?
  - kVp okay
  - Too many photons hitting film OR
  - Overdeveloped
- Bones not visible
  - kVp too high
Optical Density – Too Black
Decrease mAs

Optical Density – Too Black
Decrease kVp (& maybe mAs, too)

Too Many Photons Striking Film
• mAs too high
  – Did you remove a grid?
  – Is the tube-film distance too short?
  – Inverse square law
  – Using faster film/screen combo?
• kVp too high
  – Will cause poor contrast, even if blackness OK
• Double exposure
• Line surge
• Fog

Overdeveloped
• Incorrectly mixed developer
  – Replace developer
• Development time too long
• Developer temperature too hot

Corrected Image

Remember!
• Increase mAs → blacker
• Decrease mAs → whiter
• Increase kVp → blacker
• Decrease kVp → whiter
Optical Density Changes

• Changing mAs causes direct linear change in blackness
  – Double mAs → Twice the blackness
  – Halve mAs → Half the blackness
• Doubling mAs is approximately same as increasing kVp 10-15%
• Halving mAs is approximately same as decreasing kVp 10-15%

Optical Density

• If in doubt, err on the side of (SLIGHT) overexposure
  – Information can often be retrieved with a hot light

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Image Contrast

• The color difference between an object and the background
• Determinants:
  – Composition of object and background
    • Calcified nodule in lung – high contrast
    • Soft tissue nodule in fat – low contrast
  – Film characteristics
    • *** kVp ***
    • *** NOT mAs ***

Differential Contrast

Radiographic Contrast

• High Contrast
  – Low latitude
  – Sharp transitions
  – Black & white (short grayscale)
• Low Contrast
  – High latitude
  – Gradual transitions
  – Many gray shades (long grayscale)
Radiographic Contrast

- Subject Contrast
  - Thickness
  - Density
  - Atomic number
  - kVp
- Film Contrast
- Fog & Scatter

Thickness

Whole Tomato
Half Tomato

Tissue Density (kg/m³)

- Air 320
- Fat 910
- ST 1000
- Bone 1850

Tissue Density (kg/m³)

- Air 320
- Fat 910
- ST 1000
- Bone 1850

Atomic Number (Z)

- Air 7.6
- Fat 6.3
- ST 7.4
- Bone 13.8
- Iodine 53
- Barium 56
- Lead 82

Kilovoltage Peak (kVp)

- Low kVp
  - All photons have low energy
  - Only pass through low-density substances

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<th>Gas</th>
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Kilovoltage Peak (kVp)

- Higher kVp
  - A few photons have higher energy
  - Those few can get through denser stuff

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High kVp
- Many photon energies
- High latitude

Low kVp
- Few photon energies
- High contrast

Technique Basics

- REMEMBER!
- If you don’t like the contrast, change kVp
- BUT that will change blackness, too
- Thus, you’ll likely have to adjust mAs in the opposite direction

- Too much contrast
  - Increase kVp
Technique Basics

- Too much contrast
  - \( \rightarrow \) increase kVp
- Better grayscale (I think), but overexposed
  - \( \rightarrow \) decrease mAs

- Much better

Radiographic Contrast

- Subject Contrast
  - Thickness
  - Density
  - Atomic number
  - kVp
- Film Contrast
- Fog & Scatter

Film Contrast

- High Contrast
- High Latitude

Exposure \( \rightarrow \)

Radiographic Contrast

- Subject Contrast
  - Thickness
  - Density
  - Atomic number
  - kVp
- Film Contrast
- Fog & Scatter

Fog and Scatter

- Nondiagnostic exposure of film
  - Compton scatter
  - Heat
  - Light leaks
  - Pressure
  - Static electricity
- We’ll look artifacts next lecture & in lab
Thoracic Radiographs

- We want long contrast scale (high latitude — many grays)
  - Contrast is already high (soft tissue vs. air)
  - Much pathology of interest is subtle shadings of gray which would be burned out with high contrast technique
- Use relatively HIGH kVp
- Use relatively LOW mAs
  - Keeps blackness appropriate
  - Minimizes motion artifact

Abdominal Radiographs

- We want short contrast scale — fewer grays
  - Body contrast is low — soft tissue vs. fat
  - High contrast technique to improve visualization of differences
- Use relatively LOW kVp
- Use relatively HIGH mAs
  - Keeps blackness appropriate
Abdominal Radiographs

High Contrast – Good  High Latitude – Bad

Orthopedic Radiographs

- We want short contrast scale – fewer grays
  - Bone contrast is low – cortical bone vs. medullary bone
  - Soft tissue not as critical (but don’t ignore it)
- Use relatively LOW kVp
- Use relatively HIGH mAs
  - Keeps blackness appropriate

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Detail

- AKA Spatial Resolution
- Ability to discern 2 discrete objects as being distinct
- Measured in line pairs per mm
  - More lp/mm = better resolution
  - Typical radiograph: 7 lp/mm
  - Digital radiograph: 4-5 lp/mm

Detail Influences

- Film
  - Small vs. large silver crystals
  - Thin vs. thick emulsion
  - 1 vs. 2 emulsions
- Screen
  - Small vs. large phosphors
  - Thin vs. thick phosphor layers
- High detail requires higher technique
  - Use as high a detail as you can get away with

Unsharpness (Loss of Detail)

- Screen/Film system
- Scatter radiation
- Low contrast
- Penumbra
  - Focal spot has finite size
  - Acts as multiple point sources of X-rays
  - More severe with greater SFD
Unsharpness (Loss of Detail)

- Screen/Film system
- Scatter radiation
- Low contrast
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Unsharpness (Loss of Detail)

- Motion: Any movement during exposure
  - Patient movement
  - Portable tube movement
- Use shortest exposure time possible

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Importance of Technique

Record what you use for each patient for future reference

Technique Chart Making

- Vary:
  - kVp
  - mAs
- Keep Constant:
  - Film-screen combo
  - Processing
  - Grid
  - X-ray generator
  - Tube-film distance

Measure the thickest part
Minimize Exposure Times

- 1/5 second
- 1/30 second

Adjust the kVp

- Increase 10%
- Decrease 10%

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DR / CR Technique

- Changing kVp and mAs affect detail, NOT contrast and blackness (***)
- Choose the lowest technique that provides acceptable detail / resolution to minimize radiation exposure

DR / CR Technique

Low Technique

Higher Technique

DR / CR Contrast

- Adjustments can be performed on the monitor.
- Allows you to evaluate bone with one setting, then soft tissues with another.
What Have We Learned?

- There are lots of ways that images can lie to us
- Image blackness and contrast might show up on the test, since they were on something like 387 slides
- Radiographs made as the patient jumps off the table are not ideal