Limited Scope X-Ray Technician Course

Module 2: Introduction to Imaging Science

Presented by
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OLYMPIC HEALTH PHYSICS

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Outline

- Medical Imaging Concepts
- Image Formation
- Basic X-Ray Tube Control
- X-Ray Interactions with Tissue
- X-Ray Detectors
- Ancillary X-Ray Tube Controls
  - AEC, Collimation, Filtration, etc
- Image Quality Parameters
- Image Quality & Radiation Dose
- Window & Leveling
- PACS

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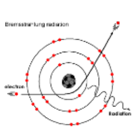
Objective

How do X-Rays create an image of the human body?



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Medical Imaging

- Primary purpose is to identify pathologic conditions
  - Ability to "see" inside the human body
- If we can accurately identify injury or illness we have increased our ability to better treat our patients
- New England Journal of Medicine
  - "Development of Body Imaging" among top 10 most important medical discoveries of last 1000 years

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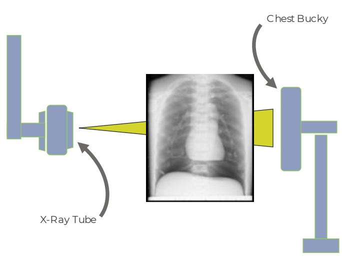

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Image Formation

- Image Formation based on
  - X-Ray tube control (kVp & mA)
  - Density and thickness of anatomical structures
  - Accurate detection of X-Ray beam
  - Computer Processing
- The intent is to create high quality images at a reasonable radiation dose

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Imaging 3D Structures

- We live in 3D – we image in 2D
  - All anatomy has dimensions of length, width, and height
  - Images only have length and height components
  - Positioning anatomical structures is critical

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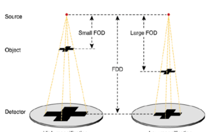
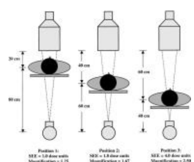
Magnification





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Basic X-Ray Tube Control

- Tube Potential (kVp)
- Tube Current (mA)
- Timer (sec or ms)
- Other Considerations
  - SID (40" vs 72")
  - AEC
  - Focal Spot Size
  - Collimation & PBL
  - Detector Type (CR/DR)
  - Grids

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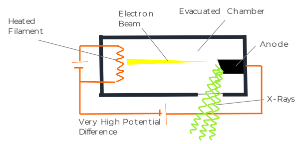
Parts of an X-Ray Tube



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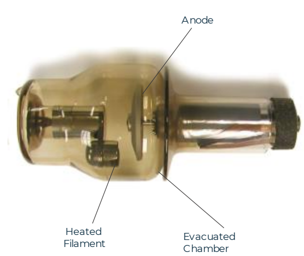

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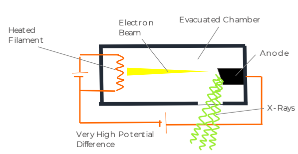
X-Ray Tube Control

- Tube Potential (kV or kVp)
  - Electrical potential applied across the X-Ray tube to accelerate electrons towards the target
  - Increasing kV will increase number of X-Rays penetrating through an object



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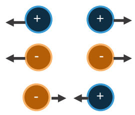
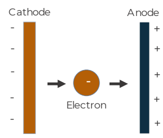
Law of Attraction

- Opposite charges attract
- Like charges repel



- Anode – Cathode Example



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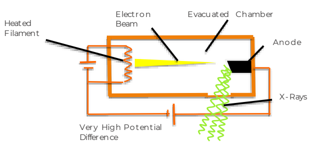

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X-Ray Tube Control

- Tube Current (mA)
  - Number of electrons accelerated across the X-Ray tube
- Timer (sec)
  - Amount of time the beam is "On"
- Tube Current Time Product (mAs)
  - Determines the total number of electrons accelerated across the X-Ray tube during the exposure
  - X-Ray Fluence → Φ
  - Serves to darken the film or add information to the detector
  - Radiation Dose is directly proportional to mAs

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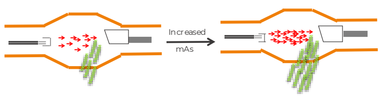
X-Ray Tube Control



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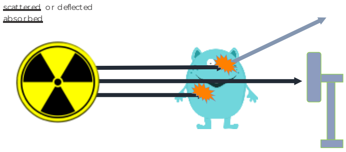
What Happens When X-Rays Hit the Human Body?

- Three things can happen
  - Pass through the body
  - Be scattered or deflected
  - Be absorbed



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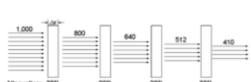
X-Rays Passing Through Tissue

- Depends on the energy of the x-ray, patient thickness, and the atomic number of the tissue
- Higher energy X-Ray
  - More likely to pass through
- Higher atomic number
  - More likely to absorb (stop) the x-ray



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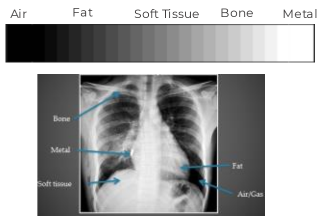
5 Basic Radiographic Densities



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X-Ray Attenuation

- X-Rays that pass through the body render the film dark (black)
- X-rays that are totally blocked do not reach the film and render the film light (white)
- Air
  - X-Rays get through → image is dark (black)
- Metal
  - X-Rays blocked → image is light (white)

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Detection of X-Ray Beam

- Only the X-Rays passing through the patient contribute to image formation
  - This can be a small fraction of the incident radiation
- Types of Imaging Receptors
  - Film
  - Computed Radiography (CR)
  - Digital Radiography (DR)

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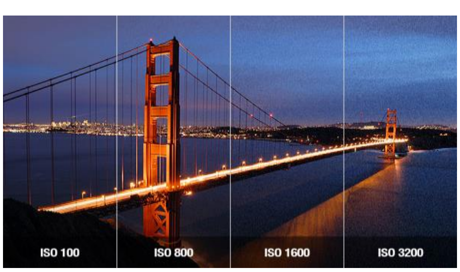
Film vs. CR vs. DR

- Film
  - Intensifying screen – scintillates when activated by X-Rays
  - Visible light exposes silver halide on film
  - More X-Rays → More visible light (linear response) → Darker Film (logarithmic response)
- Computed Radiography (CR)
  - Uses *photostimulable phosphor detector*
  - X-Rays absorbed and energy is trapped
  - Energy is "released" by a laser light
  - Light is collected and electronic signal is recorded as a digital image using pixels
- Digital Radiography (DR)
  - Use of an intensifying screen & CCD chip with an array of dexels (detector elements)
  - Forms images from visible light by collecting and reading out electrical charge

Film or Detector Speed

- Described by ISO
  - ISO measures sensitivity of detector
- Low ISO
  - Lower sensitivity but higher resolution
- High ISO
  - Higher sensitivity but noisier image
- CR generally has a lower ISO than DR
  - One reason why CR needs more information/dose



Automatic Exposure Control

- AEC is useful as an alternative to manual techniques
- Ion chambers measure amount of radiation at the detector and terminates when a preset value is reached
- Accounts for attenuation to give adequate image quality
- Reduces repeat rate

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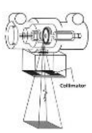
Collimation

- Collimation
  - Projected field size coincides with radiation beam
  - Limiting the field size to only the region of interest
  - Reduces radiation dose to anatomy outside of the FOV



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Is This Good Collimation?

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Is This Good Collimation?

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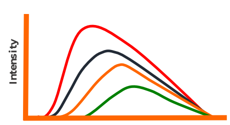
Filtration

- Removal of low energy X-Rays that will not contribute to image formation
- Filtration "hardens" the X-Ray beam
  - Reduces number of X-Rays
  - Increases the effective energy



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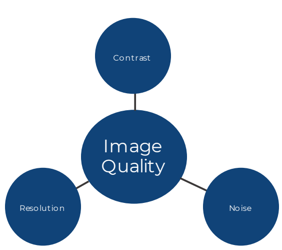

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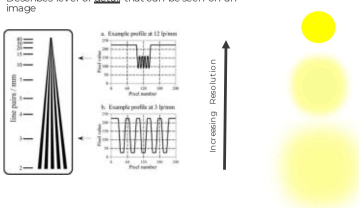
Spatial Resolution

- Describes level of detail that can be seen on an image



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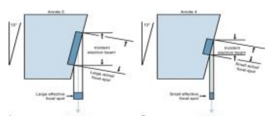
Focal Spot Size

- Small Focal Spot
  - Better Resolution
  - More Heat Loading



- Large Focal Spot
  - Greater X-Ray output intensity
  - Shorter exposure times possible

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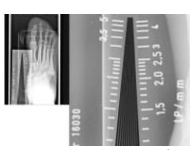
Effect of Focal Spot Size

Small Focal Spot – Resolution is 3 lp/mm



Large Focal Spot – Resolution is 1.6 lp/mm

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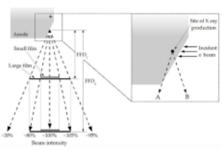
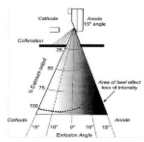
Heel Effect

- A portion of the X-Ray beam is absorbed by the anode
  - Results in less intense X-Ray beam on the anode side and more intense on the cathode side





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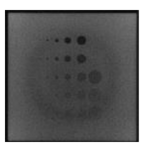
Contrast

- Ability to detect subtle changes in gray scale and distinguish from image noise



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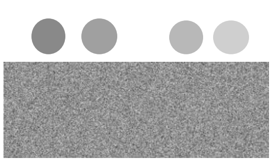
Noise

- Grain Noise
- Electronic Noise
- Structured Noise
- Anatomical Noise



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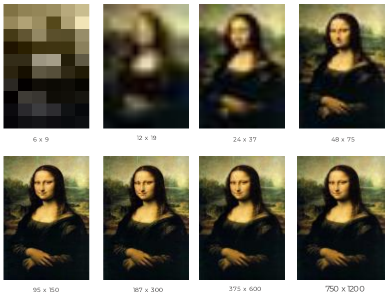

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Technique Factors & Dose

- Lower kV = Higher Radiation Dose
  - Need enough X-Rays to reach detector
  - Must be balanced with contrast needs
  - Can use higher kV with CR/DR than with film
- mAs
  - Directly proportional to radiation dose
  - mAs has different effects in Film than in CR/DR
- Generally, use high kV and low mAs to reduce patient dose
  - "Wastes" less radiation

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Image Quality & Radiation Dose

Manufacturer	50 µGy	100 µGy	200 µGy
Fuji (S)	400	200	100
Kodak (EI)	1700	2000	2300
Canon (REX)	50	100	200
Siemens (EI)	500	1000	2000

- CR/DR is quite different from film
  - mAs doesn't control OD in the same fashion
  - Use of post processing algorithms
  - Automatic and manual rescaling
- How low can you go?
  - Avoid noise and quantum mottle
- Exposure Index (EI, S, REX)
  - Can be used as a general guide
  - Varies based on manufacturer – not linear!
- Dose Creep
  - CR/DR excel with more radiation
  - Can use 10 – 50 times more mAs

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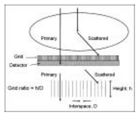
Anti-Scatter Grid

- Removes unwanted scattered radiation from reaching detector
- Parallel Grid
- Focused Grid
  - Holes point toward tube focus
  - Should only be used at a specified distance



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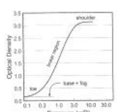
Window & Leveling

- Optical Density
  - Amount of darkening in image
- Automatic rescaling
- Hurter-Driffield Curves





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Automatic Rescaling

110 kV @ 2 mAs
EI 1460

110 kV @ 12.5 mAs
EI 2320

110 kV @ 100 mAs
EI 3210

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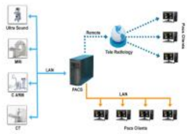
PACS

- Picture Archiving & Communication System
  - A secure network for distribution & exchange of patient information
  - Contains workstations for viewing, processing, and interpreting images
  - Archives for storage and retrieval of patient images, documentation, and reports



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Final Thoughts

- Medical Imaging is one of the most powerful tools we have in healthcare
- Understanding image formation is essential to providing the best care to our patients
  - Allows you to give the best possible image to the physician for accurate diagnosis

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